THE

# SOUTH AFRICAN JOURNAL OF SCIENCE

## VOLUME XL

BEING THE

## REPORT

OF THE

## FORTY-FIRST ANNUAL MEETING

OF THE

## SOUTH AFRICAN ASSOCIATION

FOR THE

## ADVANCEMENT OF SCIENCE

## JOHANNESBURG

1943

28th and 29th JUNE

JOHANNESBURG:
PUBLISHED BY THE ASSOCIATION
and
Printed by RADFORD, ADLINGTON, LTD., Rissik and Marshall Streets,
Johannesburg, South Africa

1943

DIE

# SUID-AFRIKAANSE JOURNAL VAN WETENSKAP

## DEEL XL

SYNDE DIE

## VERSLAG

VAN DIE

## EEN-EN-VEERTIGSTE JAARVERGADERING

VAN DIE

## SUID-AFRIKAANSE GENOOTSKAP

VIR DIE

## BEVORDERING VAN WETENSKAP

## JOHANNESBURG

1943

28 en 29 JUNIE

JOHANNESBURG:
UITGEGEE DEUR DIE GENOOTSKAP
en
Gedruk deur RADFORD, ADLINGTON, LTD., Rissik-en Marshallstraat,
Johannesburg, Suid-Afrika

1943

*New Delhi*



## CONTENTS.

THE

# SOUTH AFRICAN JOURNAL OF SCIENCE

BEING THE REPORT OF THE

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

(1943, JOHANNESBURG)

Vol. XL NOVEMBER, 1943 Vol, XL

## EDITORIAL NOTE.

Owing to the shortage of paper it has been necessary to publish 14 of the 57 papers read before the annual congress in June last either in abstract or in title only.

I am indebted to Dr. Juritz, Dr. A. L. du Toit, Prof. H. H. Paine and Mr. Jas. Gray for writing or procuring obituary notices of some of the distinguished members of the Association whom we lost during the past year, and I have to thank many contributors for the prompt return of proofs and for their kind assistance in abridging their papers when desirable.

S. B. Asher

Honorary Associate Editor.

# OFFICERS AND COUNCIL FOR 1943-44
# AMPSDRAERS EN RAAD VIR 1943-44

**PATRON/BESKERMHEER**

HIS MAJESTY THE KING/SY MAJESTEIT DIE KONING.

**President:** Col./Kol. J. G. Rose, P.O. Box 1549, Cape Town.

**Past/Oud President:** Dr. A. Pijper, 57 Celliers Street, Pretoria.

**Vice-Presidents**

Mr. T. D. Hall, Box 1122, Johannesburg; Dr. S. H. Skaife, P.O. Box 13, Cape Town; Mr. E. B. Dunkerton, P.O. Box 266, Durban; Mr. F. W. Storey, St. Andrew's School, Bloemfontein.

**Hon General Secretaries**

Dr. C. F. Juritz, P.O. Box 1644, Cape Town; Professor H. H. Paine, The University, Johannesburg.

**Hon. General Treasurer:** Mr. Jas. Gray, P.O. Box 5254, Johannesburg.

**Hon. Editor of Publications:** Professor John Phillips, The University, Johannesburg.

**Hon. Associate Editor:** Mr. S. B. Asher, 51 Fortescue Road, Yeoville, Johannesburg.

**Hon. Librarian:** Mr. P. Freer, The University, Johannesburg.

**Assistant General Secretaries**

The Associated Scientific and Technical Societies of South Africa, Kelvin House, P.O. Box 6894, Johannesburg.

**Ordinary Members of Council**

TRANSVAAL

*Witwatersrand*

Mr. S. B. Asher
Dr. A. E. H. Bleksley
Mr. R. Craib
Dr. E. J. Hamlin
Mr. R. H. Harriss
Prof. P. R. Kirby
Mr. A. J. Limebeer
Prof. I. D. MacCrone
Prof. L. F. Maingard
Prof. John Orr
Mr. F. R. Paver
Dr. J. B. Robertson
Prof. G. H. Stanley
Dr. L. H. Wells

*Pretoria*

Prof. G. de Kock
Dr. P. J. du Toit
Dr. R. A. Dryer
Dr. F. E. T. Krause
Dr. M. G. Mes
Dr. E. Percy Phillips

*Potchefstroom*

Prof. A. P. Goossens

NATAL

*Pietermaritzburg and Outlying Districts*

Prof. A. W. Bayer
Mr. J. R. H. Coutts

*Durban*

Mr. E. C. Chubb
Mr. H. H. Dodds
Mr. J. F. Schofield

PROVINCE OF THE CAPE OF GOOD HOPE

*Cape Town*

Col. C. Graham Botha
Prof. M. R. Drennan
Dr. A. L. du Toit
Mr. A. J. H. Goodwin
Mr. G. W. Lyon
Prof. I. Schapera

*Stellenbosch and District*

Mr. F. J. S. Anders
Prof. C. G. S. de Villiers

*Kimberley*

Mr. J. H. Power

*Grahamstown, Kingwilliamstown and District*

Prof. J. Omer-Cooper

*Oudtshoorn*

Dr. M. Boehmke

*East London and Port Elizabeth*

Dr. P. W. Laidler

*Outside Districts*

Dr. H. E. Wood

ORANGE FREE STATE

Dr. E. C. N. van Hoepen

SOUTHERN RHODESIA

Mr. H. B. Maufe

**Trustees**

*Endowment Fund*

Mr. A. V. H. Carter
Prof. L. Crawford
Prof. John Orr

*South African and British Association Medal Funds*

Hon. J. H. Hofmeyr
Prof. L. F. Maingard

**Bulletin Committee**

Col. J. G. Rose (President)
Prof. John Phillips (Editor), Chairman
Mr. S. B. Asher (Hon. Associate Editor)
Mr. P. Freer
Mr. Jas. Gray
Mr. T. D. Hall
Prof. L. F. Maingard
Prof. H. H. Paine
Mr. F. R. Paver
Prof. G. H. Stanley (Chairman of Recorders' Committee)

**Publications Committee**

The Hon. Editor (Chairman), The President, The Hon. Associate Editor, The Hon. General Secretaries, The Hon. Treasurer, The Hon. Librarian, Prof. L. F. Maingard, and the Recorders of Sections.

## PROCEEDINGS OF THE FORTY-FIRST ANNUAL GENERAL MEETING OF MEMBERS, HELD AT KELVIN HOUSE, JOHANNESBURG, ON TUESDAY, 29th JUNE, 1943, AT 12 NOON.

## VERRIGTINGS VAN DIE EEN-EN-VEERTIGSTE ALGEMENE JAARVERGADERING VAN LEDE IN KELVIN-HUIS, JOHANNESBURG, OM TWAALF UUR OP DINSDAG 29 JUNIE GEHOU.

PRESENT/TEENWOORDIG.—Dr. A. Pijper (President), Dr. H. L. Alden, Mr./Mnr. S. B. Asher, Professor W. F. Barker, Dr. A. E. H. Bleksley, Dr. R. Broom, Dr. A. L. du Toit, Dr. C. A. du Toit, Dr. R. A. Dyer, Mr./Mnr. E. M. P. Evans, Mr./Mnr. C. Ferguson, Mr./Mnr. V. F. Fitzsimons, Dr. F. W. Fox, Mr./Mnr. P. Freer, Mr./Mnr. James Gray, Dr. E. J. Hamlin, Mr./Mnr. J. Harcus, Mr./Mnr. A. Hossack, Dr. R. J. A. Jordan, Professor P. R. Kirby, Miss/Mej. F. M. Lanham, Mr./Mnr. B. D. Malan, Mr./Mnr. D. B. D. Meredith, Dr. M. G. Mes, Mr./Mnr. A. O. D. Mogg, Mrs./Mev. M. Moss, Miss/Mej. J. M. Murray, Mr./Mnr. E. F. G. Nelson-Tansley, Dr. R. J. Ortlepp, Mr./Mnr. F. R. Paver, Dr. E. Percy Phillips, Dr. Bernard Price, Dr. J. I. Quin, Dr. E. M. Robinson, Colonel/Kol. J. G. Rose, Mr./Mnr. J. Lyall Soutter, Professor G. H. Stanley, Dr. H. van Gent, Professor C. van Riet Lowe, Dr. H. Weinmann, Dr. L. H. Wells, Miss/Mej. E. E. Wijers, Dr. H. E. Wood, Professor H. H. Paine (Honorary General Secretary/Ere-algemene Sekretaris), and Mr. A. J. Adams (Assistant General Secretary/Assistent-algemene Sekretaris).

1. GREETINGS AND APOLOGIES. — Telegrams were read from the Durban members of Council and from Captain H. A. G. Jeffreys apologising for their absence and extending their best wishes for a profitable meeting.

GROETE EN VERONTSKULDIGINGS.—Telegramme is gelees van die Durbanse lede van die Raad en van Kaptein H. A. G. Jeffreys, met verontskuldigings vir hulle afwesigheid en beste wense vir 'n nuttige vergadering.

It was noted that apologies for absence had been received from/

Ontvange verontskuldigings vir afwesigheid is genoteer van Professor A. W. Bayer, Mr./Mnr. J. R. H. Coutts, Dr. G. de Kock, Dr. P. J. du Toit, Mr./Mnr. T. D. Hall, Dr. F. E. T. Krause, Mr./Mnr. A. J. Limebeer, Professor L. F. Maingard, Professor John Orr, Professor John Phillips, Mr./Mnr. J. H. Power, Dr. J. B. Robertson and/en Dr. D. G. Steyn.

Dr. S. F. Bush stated that he had been requested by Professor A. W. Bayer, Mr. J. R. H. Coutts and Mrs. S. F. Bush to extend their greetings to the meeting.

Dr. S. F. Bush het meegedeel dat Professor A. W. Bayer, Mnr. J. R. H. Coutts en Mevr. S. F. Bush hom versoek het om hulle groete aan die vergadering oor te bring.

2. MINUTES.—The Minutes of the Fortieth Annual General Meeting, held at Johannesburg on the 30th June, 1942, and printed on pages iv to vi of the Report of the Johannesburg Session (Volume XXXIX of the Journal) were confirmed.

NOTULE.—Die Notule van die Veertigste Algemene Jaarvergadering gehou in Johannesburg op 30 Junie 1942 en gedruk op bladsye IV tot VI van die Verslag van die Johannesburgse Byeenkoms (Deel XXXIX van die Journal) is goedgekeur.

3. ANNUAL REPORT OF COUNCIL FOR THE YEAR ENDED 30TH JUNE, 1943.—The Annual Report of the Council for the year ended 30th June, 1943, having been duly suspended on the Notice Board, was taken as read and adopted.

JAARVERSLAG VAN DIE RAAD VIR DIE JAAR TOT OP 30 JUNIE, 1943. —Die Jaarverslag van die Raad vir die jaar tot op 30 Junie 1943, wat behoorlik op die Kennisgewingsbord gepubliseer was, is as gelees beskou en goedgekeur.

4. ANNUAL REPORT OF THE HONORARY GENERAL TREASURER AND STATEMENT OF ACCOUNTS FOR THE YEAR ENDED 31ST MAY, 1943.—The Honorary General Treasurer's Report and the Statement of Accounts for the year ended 31st May, 1943, having been duly displayed on the Notice Board, were taken as read and adopted.

JAARVERSLAG VAN DIE ERE-ALGEMENE PENNINGMEESTER EN STAAT VAN REKENINGE VIR DIE JAAR TOT OP 31 MEI 1943.—Die verslag van die Ere-algemene Penningmeester en die Staat van Rekeninge vir die jaar tot op 31 Mei 1943, wat behoorlik op die Kennisgewingsbord gepubliseer is, is as gelees beskou en goedgekeur.

5. ANNUAL REPORT OF THE HONORARY LIBRARIAN FOR THE YEAR ENDED 31ST MAY, 1943.—The Annual Report of the Honorary Librarian for the year ended 31st May, 1943, having been duly suspended on the Notice Board, was taken as read and adopted.

JAARVERSLAG VAN DIE ERE-BIBLIOTEKARIS VIR DIE JAAR TOT OP 31 MEI 1943.—Die verslag van die Ere Bibliotekaris vir die Jaar tot op 31 Mei 1943, wat behoorlik op die Kennisgewingsbord gepubliseer is, is as gelees beskou en goedgekeur.

6. ELECTION OF GENERAL OFFICERS AND MEMBERS OF COUNCIL FOR 1943/1944.—The names of members elected as General Officers and members of the Council for the year 1943/1944 are given on page ii.

VERKIESING VAN ALGEMENE AMPSDRAERS EN RAADSLEDE VIR 1943/1944.—Die name van die lede wat tot algemene Ampsdraers en Raadslede vir die jaar 1943/44 gekies is, kom voor op bladsy ii.

7. Colonel J. G. Rose expressed his appreciation of the honour conferred upon him by his election as President for the 1943/44 Session.

Kol. J. G. Rose het sy waardering uitgespreek van die eer wat hom bewys is deur sy verkiesing tot President vir die 1943/44-Byeenkoms.

8. SUBSCRIPTIONS OF ASSOCIATE AND STUDENT MEMBERS.—It was agreed to confirm the action of the Council in making the subscription for Associate Members for the 1943 Annual Meeting to be ten shillings and for Student Members to be five shillings instead of one pound and ten shillings and sixpence respectively, it being noted that this action had been taken as a result of the curtailment of the Meeting to two days.

LEDEGELD VAN ASPIRANT- EN STUDENTLEDE.—Dit is ooreengekom om die handeling van die Raad, nl. die vasstel van ledegeld vir Aspirantlede vir die 1943-Jaarvergadering op tien sjielings en vir Studentlede op vyf sjielings, in plaas van een pond en tien sjielings en ses pennies respektiewelik, te bekragtig, terwyl aangeteken is dat hierdie besluit geneem is as gevolg van die verkorting van die Vergadering tot twee dae.

9. PRESERVATION OF PRE-HISTORIC ROCK ENGRAVINGS AND GLACIAL STRIATIONS AND HERD OF HARTEBEESTE ON THE FARMS NOOITGEDACHT AND KLIPFONTEIN.—It was reported that the Council had passed the following resolution at its June meeting, and had despatched copies to the Prime Minister, the Minister of Mines and Minister of the Interior:—

"Whereas it has come to our notice that requests are being made for the proclamation of the farms Nooitgedacht and Klipfontein as diamond diggings, and whereas this would result in the loss to the country of some of the most valuable prehistoric rock engravings and glacial striations that exist in the world, as well as the loss of a herd of two thousand hartebeeste now living on these farms, we, the Council of the South African Association for the Advancement of Science, most earnestly request the Government to continue with the preservation of these regions for posterity."

The action taken by the Council was confirmed.

BEHOUD VAN VOOR-HISTORIESE ROTSGRAVURES EN YS-STREPINGS EN VAN DIE TROP HARTBEESTE OP DIE PLASE NOOITGEDACHT EN KLIPFONTEIN.—Dit is meegedeel dat die Raad op sy Junie-vergadering die volgende besluit aangeneem het, en dat afskrifte daarvan aan die Eerste Minister, die Minister van Mynwese en die Minister van Binnelandse Sake gestuur is: —

"Aangesien dit onder ons aandag gebring is dat versoeke gedoen word vir die proklamasie van die plase Nooitgedacht en Klipfontein tot diamantdelwerye en aangesien dit die verlies vir ons land ten gevolge sou hê van sommige van die waardevolste voor-historiese rotsgravures en ysstrepings in die wêreld, sowel as die verlies van 'n trop van twee duisend hartbeeste op hierdie plase, versoek ons, as Raad van die Suid-Afrikaanse Genootskap vir die Bevordering van Wetenskap, die Regering dringend om hierdie streke vir die nageslag te behou."

Die handeling van die Raad is goedgekeur.

10. RESOLUTIONS FROM SECTIONS / BESLUITE VAN AFDELINGS.

(a) *Resolution from Section D (proposed by Dr. R. J. Ortlepp):*

"That whereas it is a well known biological law that concentration of population of any species invariably brings with it such evils as disease, overstocking, trampling of the veld, destruction of the natural flora, malnutrition, and mass migration; that whereas sanctuaries cannot be isolated from the country's economy with the interests of agriculture on the one hand and of game preservation on the other; that whereas a great deal of investigation has been done in South Africa on veld management and in the control of animal disease for the advancement of agriculture; and that whereas the ecological problems in the sanctuaries have as yet received little consideration, this Section recommends that the Council of the South African Association for the Advancement of Science be asked to consider a scheme by means of which it will be possible to reorientate the policy of the sanctuaries and to endeavour to centralise as far as it is possible at present all existing organisations associated with the protection and control of the fauna, flora and sanctuaries in South Africa, and that provision be made for adequate scientific collaboration in developing and safeguarding these unique sanctuaries."

(a) *Besluit van Afdeling D (Voorstel Dr. R. J. Ortlepp):*

"Dat, aangesien dit 'n welbekende biologiese wet is dat konsentrasie van bevolking van enige soort altyd sulke euwels soos siekte, oorlaaiïng, veldvertrapping, vernietiging van die natuurlike flora, ondervoeding, en massatrek saambring; dat, aangesien sanctuaria nie uit die land se staathuishoudkunde uitgesluit kan word nie, met die belange van landbou aan die een kant en van wildbeskerming aan die ander kant; dat, aangesien in Suid-Afrika baie ondersoekingswerk in verband met veldbestuur, en vir die beheer van dieresiektes vir die bevordering van landbou gedoen is; en dat, aangesien die

ekologiese probleme in die sanctuaria tot nog toe slegs min aandag ontvang het, beveel hierdie Afdeling aan dat die Raad van die Suid-Afrikaanse Genootskap vir die Bevordering van Wetenskap versoek word om 'n skema op te stel en te oorweeg waardeur dit moontlik sal wees om die beleid van die sanctuaria te her-oriënteer en om pogings aan te wend om, vir sover dit op die oomblik moontlik is, alle bestaande organisasies wat met die beskerming en die beheer van die fauna, flora en sanctuaria in Suid-Afrika verbind is, te sentraliseer, en dat voorsiening gemaak word vir voldoende wetenskaplike saamwerking by die ontwikkeling en beskerming van hierdie unieke sanctuaria."

(b) *Resolution from Section E (proposed by Dr. R. Broom):*

"In view of the historical, scientific and aesthetic value of the valley which includes the great caves of Makapans, in the district of Potgietersrust, this Association recommends the acquisition by the State of about 1,000 morgen of the farms Makapans and Swartkrans to be set aside as a Nature Reserve for administration by the National Parks Board of Trustees."

It was agreed to adopt the above resolutions and to refer them to the Council for action.

(b) *Besluit van Afdeling E (Voorstel Dr. R. Broom):*

"Met die oog op die geskiedkundige, wetenskaplike en estetiese waarde van die vallei wat die groot grotte van Makapans in die distrik Potgietersrust insluit, beveel hierdie Genootskap die aankoop deur die Staat aan van ongeveer 1000 morg van die plase Makapans en Swartkrans om afgesonder te word as 'n Natuurlike Reserve onder die administrasie van die Nasionale Parkeraad van Kuratore."

Dit is goedgekeur om die bostaande besluite aanteneem en hulle na die Raad te verwys vir behandeling.

11. General Extension of Research Activities in the Union of South Africa.—On the proposal of Professor W. F. Barker, seconded by Dr. F. W. Fox, the following resolution was adopted and referred to the Council:—

"Having regard—

(1) to the objects of the Association, one of which is 'to give a stronger impulse and a more systematic direction to scientific enquiry and research';

(2) to the past efforts made by the Association to give effect to this aim, notably during the years 1934/7;

(3) to the growing urgency for a scientific approach to the many problems of importance in relation to the future development of South Africa, and the increasing realisation by scientists of their responsibilities to the community, and being of opinion that the proportion of the national income devoted to research purposes (even when expenditure from private sources is included) is but a small fraction of the 1 per cent. which a comparison with other countries would show to be desirable;

this General Meeting of the Association considers that a general extension of research activities to be vital and urgent in the national interest, and that the attention of the Government should be drawn to this need with the maximum possible emphasis."

Algemene Uitbreiding van Navorsingswerk in die Unie van Suid-Afrika.—Op voorstel van Professor W. F. Barker, gesekondeer deur Dr. F. W. Fox, is die volgende besluit aangeneem en na die Raad verwys:—

"Met inagneming van—

(1) die oogmerke van die Genootskap, een waarvan is 'om 'n sterker aansporing tot en 'n sistematieser rigting aan wetenskaplike ondersoek en navorsing te gee';

(2) die pogings wat in die verlede deur die Genootskap gedoen is om hierdie doel, besonderlik gedurende die jaar 1934/7, te bereik;

(3) die groeiende noodsaaklikheid om die baie belangrike probleme met betrekking tot die toekomstige ontwikkeling van Suid-Afrika en die toenemende erkenning deur wetenskaplikes van hulle verantwoordelikheid aan die gemeenskap, en van mening synde dat die deel van die nasionale inkomste wat aan navorsingsdoeleindes bestee word (selfs al word uitgawe uit private bronne ingesluit) slegs 'n klein deeltjie van die een persent is wat in vergelyking met ander lande as wenslik sou beskou word,

word 'n algemene uitbreiding van navorsingsbedrywighede in die volksbelang as noodsaaklik en dringend beskou. Die aandag van die Regering behoort op hierdie noodsaaklikheid met die grootste moontlike nadruk gevestig te word."

12. ANNUAL MEETING, 1944.—In view of the international situation, it was agreed that the Council have power to decide the date, duration and venue of the 1944 Annual Meeting.

JAARVERDERING, 1944.—Met die oog op die internasionale omstandighede is besluit dat die Raad mag sal hê om die datum, duur en plek van die 1944-Jaarvergadering vas to stel.

13. VOTE OF THANKS.—On the proposal of Colonel J. G. Rose, a unanimous vote of thanks was accorded firstly to the Associated Scientific and Technical Societies of South Africa for providing the necessary accommodation for the holding of the Annual Meeting in Kelvin House and for granting the privilege of Honorary Membership to visiting members attending the meeting, secondly to the Honorary Auditors, Messrs. Alex. Aiken & Carter, for their services in carrying out the audit for the year 1942/1943, and finally to the Press for their services in reporting the proceedings of the Annual Meeting.

Mr. James Gray proposed a hearty vote of thanks to the President for the valuable services he had rendered the Association during his term of office, and for the able manner in which he had conducted the meetings over which he had presided, this vote of thanks being carried with acclamation.

MOSIE VAN DANK.—Op voorstel van Kolonel J. G. Rose is eenparig die dank van die vergadering gebring, in die eerste plek aan die Verenigde Wetenskaplike en Tegniese Vereniginge van Suid-Afrika vir die verskaffing van die nodige geleentheid vir die hou van die Jaarvergadering in Kelvin-Huis en vir die verleen van Ere-Lidmaatskap aan besoeker-lede van die Vergadering: in die tweede plek aan die Ere-Ouditeure, die firma Alex Aiken en Carter, vir hulle gedienstige Ouditering vir die Jaar 1942/1943, en tenslotte aan die Pers vir sy verslae van die verrigtings van die Jaarvergadering.

Mnr. James Gray het 'n mosie van hartlike dank aan die President voorgestel vir sy waardevolle dienste wat hy gedurende sy ampstyd aan die Genootskap bewys het en vir die bekwame wyse waarom hy die vergaderings as Voorsitter gelei het. Hierdie mosie is met toejuiging aangeneem.

## REPORT OF COUNCIL FOR YEAR ENDING 30TH JUNE, 1943.
## VERSLAG VAN DIE RAAD VIR DIE JAAR TOT OP 30 JUNIE 1943.

1. OBITUARY/IN MEMORIAM.—Your Council reports with regret the deaths of the following members/U Raad gee met leedwese kennis van die oorlyde van die volgende lede:—Professor H. Bell-John, Dr. W. G. Bennie, Mr./Mnr. J. F. Ferreira, Dr. F. G. C. Fleischer, Rev./Eerw. Dr. W. Flint (Past President and Foundation Member/Oud President en Oprigter-Lid,, Dr. T. N. Leslie (Honorary Life Member/Lewenslange Erelid), Mr./Mnr. F. J. Lewis, Professor W. H. Logeman, Mr./Mnr. P. R. Malleson, Dr. B. de C. Marchand, Dr. T. Reunert (Past President, Honorary Life Member and Foundation Member/Oud-President, Lewenslange-Erelid en Oprigter-Lid), Mrs./Mev. T. A. E. Rosenbrock-Drege, Dr. H. A. Spencer, Mr/Mnr. J. D. Stevens and en Dr. Bertha Stoneman.

2. MEMBERSHIP.—Since the last Report thirty-four members have joined the Association, fifteen have died, and nine have resigned, and the names of four members have been removed from the membership list.

The following table shows a comparative list of the geographical distribution of membership as at the 30th June, 1942, and the 30th June, 1943:—

LEDETAL.—Sedert die jongste verslag het vier-en-dertig lede by die Genootskap aangesluit, veertien is oorlede en nege het bedank. Die name van vier lede is van die Ledelys geskrap.

Die volgende lys toon, vergelykenderwys, die geografiese voorkoms van lede op 30 Junie 1942 en 30 Junie 1943:—

| | 1942. | 1943. |
|---|---|---|
| Transvaal ... .. ... ... | 320 | 333 |
| Cape of Good Hope ... ... ... | 155 | 154 |
| Natal ... ... ... ... ... | 75 | 70 |
| Orange Free State ... ... ... | 19 | 19 |
| Southern and Northern Rhodesia | 10 | 11 |
| South-West Africa ... ... ... | 2 | 1 |
| Mocambique ... ... ... ... | 2 | 2 |
| Abroad ... ... ... ... | 23 | 22 |
| | 606 | 612 |

3. HONORARY LIFE MEMBERSHIP.—M. l'Abbé H. E. P. Breuil and Dr. E. L. Gill were elected Honorary Life Members of the Association.

LEWENSLANGE ERELEDE. — M. l'Abbé H. E. P. Breuil en Dr. E. L. Gill is tot Lewenslange Erelede van die Genootskap gekies.

4. THE JOURNAL.—Volume XXXIX of the "South African Journal of Science," being the Annual Report of the Association for the year ended 30th June, 1942, was placed in the hands of members in February, 1943. It consisted of 411 pages and contained the seven Presidential Addresses and 33 other Papers in full or in abstract, together with Indexes, Accounts, etc.

DIE "JOURNAL." — Deel XXXIX van die Suid-Afrikaanse Journal van Wetenskap, wat die Jaarverslag van die Genootskap vir die jaar tot op 30 Junie 1942 bevat, is in Februarie 1943 aan die lede voorgelê. Dit het uit 411 bladsye bestaan en het die sewe Voorsitterstoesprake en 33 lesings, volledig of in abstracto, benewens inhoudsopgawe, rekeninge, ens., bevat.

5. QUARTERLY BULLETINS.—Three Bulletins were issued during the year under review, in October, 1942, in April, 1943, and in June, 1943, respectively.

KWARTAAL-BULLETINS. — Gedurende die jaar is drie bulletins uitgegee, respektiewelik in Oktober 1942, in April 1943, en Junie 1943.

6. SOUTH AFRICA MEDAL AND GRANT / SUID-AFRIKA-MEDALJE EN SKENKING.—Your Council has awarded the South Africa Medal, together with a grant of £51 8s. 8d., to Professor B. F. J. Schonland. The recommendation was made by the Medal Committee, consisting of the following members: —

U Raad het die Suid-Afrika-Medalje, saam met 'n skenking van £51 8 8 toegeken aan Professor B. F. J. Schonland. Die aanbeveling is gedoen deur die Medalje-Komitee, bestaande uit die volgende lede:

Dr. A. Pijper (Chairman), Dr. S. F. Bush, Professor C. G. S. de Villiers, Dr. A. L. du Toit, Dr. P. J. du Toit, Mr./Mnr. T. D. Hall, Professor P. R. Kirby, Professor W. J. Lutjeharms, Professor I. D. MacCrone, Professor L. F. Maingard, Dr. E. Percy Phillips and/en Dr. H. E. Wood. The Secretary of the British Association has been notified of the award.

Die Sekretaris van die Britse Genootskap is van die toekenning in kennis gestel.

7. BRITISH ASSOCIATION MEDAL/-MEDALJE, 1943.—The Council of the British Association has awarded the British Association Medal and Grant to Miss K. Pentz for her paper entitled "The Cranial Morphology of the Neotropical Microhylid *(Anura) Elachistocleis Ovalis* (Schneider)."

Die Raad van die Britse Genootskap het die "British Association Medal" en Skenking toegeken aan Mej. K. Pentz, vir haar lesing getitel "Die Skedelvormleer van die Neotropiese Microhylid *(Anura) Elachistocleis Ovalis* (Schneider)."

8. DONATIONS/GIFTE.—The thanks of the Association are due to the Honourable the Minister of Finance and of Education for a grant of £250 towards the expenses of the publication of the Journal, and to the Johannesburg Municipality for a grant of £100.

Die Genootskap spreek sy dank uit aan Sy Ed. die Minister van Finansië en Onderwys vir 'n gif van £250 tot die onkoste van die uitgawe van die Journal, en aan die Johannesburgse Munisipaliteit vir 'n toelae van £100.

9. SECRETARIAL FEES/SEKRETARIAAT-HONORARIUM. — Following a request from the Associated Scientific and Technical Societies of South Africa, your Council has increased the secretarial fees paid to the Associated Societies from £15 per month to £20 per month, to help in paying the cost of living allowances to their present staff and the allowances to members of the staff on active service. The increase is a temporary one, and came into effect on 1st May, 1943.

Ingevolge 'n versoek van die "Verenigde Wetenskaplike en Tegniese Verenigings van Suid-Afrika" het u Raad die Sekretariaat-honorarium, wat aan die verenigings betaal word, van £15 per maand tot £20 per maand verhoog, as 'n bydrae tot die lewenskostetoelae vir hulle huidige personeel en die toelae aan lede van hulle personeel wat op aktiewe diens is. Die verhoging is tydelik en dateer van 1 Mei 1943.

10. POLICY OF THE ASSOCIATION/BELEID VAN DIE GENOOTSKAP.—In accordance with the policy of the Association as enunciated in the Report of Council for the year ending 30th June, 1940 (Vol. 37, p. vii), providing "that both official languages shall receive equal recognition and that this principle shall be given practical effect as far as the financial position of the Association allows," the Council has decided that the title pages of the Association's Journal and Bulletin, the Annual Reports of the Council and Officers of the Association, and the Minutes of Annual General Meetings shall appear in English and

Afrikaans. Already a number of paragraphs of an official nature in Bulletins Nos. 2 and 3 of the past year have been published in both languages, and the practice will be continued in Volume 40 of the Journal and in subsequent issues of the Bulletin.

Ooreenkomstig die beleid van die Genootskap, soos uiteengesit in die Verslag van die Raad vir die jaar tot op 30 Junie 1940 (Deel 37, Bl. VII), wat bepaal "Dat beide amptelike tale gelyke erkenning sal kry en dat hierdie beginsel prakties toegepas sal word vir sover die geldelike toestand van die Genootskap dit toelaat," het die Raad besluit dat die Titelbladsye van die Genootskap se Journal en Bulletin, die Jaarverslae van die Raad en Ampsdraers van die Genootskap, en die Notule van Algemene Jaarvergaderinge, in Engels en Afrikaans sal verskyn. 'n Aantal paragrawe van 'n amptelike aard in Bulletins Nos. 2 en 3 van verlede jaar is alreeds in beide tale gepubliseer en hierdie beleid sal in Deel 40 van die Journal en in volgende uitgawes van die Bulletin voortgesit word.

11. Annual Meeting/Jaarvergadering, 1943.—In accordance with the instruction given at the Annual General Meeting in 1942, your Council again arranged a short session to be held in Johannesburg at the end of June. The meeting has occupied the two days, 28th and 29th June. A symposium on "Social Security in South Africa under the Existing Economic System" had been planned for a third day, but the arrangements broke down on account of the incidence of the General Election.

Ooreenkomstig die instruksies op die Algemene Jaarvergadering in 1942 het u Raad weer 'n kort sitting georganiseer, wat op die end van Junie in Johannesburg gehou sou word. Die Vergadering het twee dae, 28 en 29 Junie, in beslag geneem. 'n Symposium oor "Bestaansekerheid in Suid-Afrika onder die huidige ekonomiese stelsel" was bedoel vir 'n derde dag, maar die reëlings het, weens die Algemene Verkiesing, in duie geval.

12. The New Council/Die Nuwe Raad.—On the basis of membership provided in the Constitution, Section 22, the numbers of members of Council assigned for the distribution of each centre during the ensuing year should be distributed as follows:—

Die aantal Raadslede vir elke sentrum, gedurende die volgende jaar, moet, soos in die Statute, Artikel 22, bepaal, op die basis van die ledetal as volg verdeel word:—

| | |
|---|---|
| **Transvaal:** | |
| Witwatersrand | 14 |
| Pretoria | 6 |
| Outside Districts/Buitedistrikte | 1 |
| **Province of the Cape of Good Hope:** | |
| Cape Peninsula and District/en Distrikt | 6 |
| Stellenbosch and District/en Distrikt | 2 |
| East London and/en Port Elizabeth | 1 |
| Grahamstown, Kingwilliamstown and District/en distrikt | 1 |
| Kimberley | 1 |
| Oudtshoorn | 1 |
| Outside Districts/Buitedistrikte | 1 |
| **Natal:** | |
| Durban and District/en Distrikt | 3 |
| Pietermaritzburg and Outside Districts/en Buitedistrikte | 2 |
| **Orange Free State:** | |
| Bloemfontein and District/en Distrikt | 1 |
| **Southern Rhodesia** | 1 |
| | 41 |

13. HONORARY AUDITORS/ERE-OUDITEURS.—The thanks of the Association are again due to Messrs. Alex. Aiken & Carter, who have been Honorary Auditors to the Association for many years, for carrying out the audit for the year 1942-1943.

Nogmaals spreek die Genootskap sy dank uit aan die firma Alex. Aiken en Carter, wat al jare lank ere-ouditeurs van die Genootskap is, vir die ouditering vir die jaar 1942-1943.

14. SECRETARIAT/SEKRETARIAAT. — The Associated Scientific and Technical Societies of South Africa continue to act as Assistant General Secretaries of the Association, and your Council would like to express its appreciation of these services, and particularly to thank Mr. A. J. Adams and Mr. I. M. Sinclair for the assistance they have rendered.

Die Verenigde Wetenskaplike en Tegniese Verenigings van Suid-Afrika bly as Assistent-Algemene Sekretarisse van die Genootskap ageer en u Raad wil sy waardering van hierdie dienste uitspreek en in besonder Mnre A. J. Adams en I. M. Sinclair bedank vir die hulp wat hulle verleen het.

## REPORT OF HONORARY GENERAL TREASURER FOR THE YEAR ENDED 31ST MAY, 1943.

The Income and Expenditure Account reflects a satisfactory result for the year. While the JOURNAL expenses are £42 more than last year, most of the other figures on the expenditure side are similar to last year. The income from subscription is, with arrears, £57 greater. The excess of income over expenditure is £173, which is £31 less than that of last year—a very satisfactory position in these abnormal times.

Next year the Association will have to meet increased expenditure in connection with the printing of the JOURNAL and, in addition, as explained in the Annual Report, it is called upon to meet an increased charge of £60 in secretarial fees on account of cost of living and military allowances.

The thanks of the Association must be expressed again to the Union Department of Education for the continuance of the grant of £250 towards JOURNAL expenses and to the City Council of Johannesburg for again contributing so generously.

JAS. GRAY,

*Honorary General Treasurer.*

## VERSLAG VAN DIE ERE-ALGEMENE PENNINGMEESTER, VIR DIE JAAR TOT OP 31 MEI 1943.

Die Inkomste- en Uitgawerekening gee 'n bevredigende resultaat vir die jaar aan. Terwyl die Journal-onkoste £42 meer is as verlede jaar, is die ander bedrae aan die Uitgaafkant dieselfde as van die vorige jaar. Die inkomste van ledegeld is, saam met agterstallige bedrae, £57 meer. Die verskil van Inkomste bo Uitgawe is £173, wat £31 minder is as verlede jaar—'n baie bevredigende toestand in hierdie abnormale tye.

Aanstaande jaar sal die Genootskap groter uitgawe hê in verband met die druk van die Journal en boonop, soos in die Jaarverslag verduidelik, sal 'n addisionele bedrag van £60 vir Sekretariële onkoste betaal moet word vir lewenskoste- en militêre toelae.

Nogmaals moet die dank van die Genootskap uitgespreek word aan die Unie-Onderwysdepartement vir die vernuwing van die skenking van £250 vir Journal-onkoste, en aan die Stadsraad van Johannesburg vir sy herhaalde milde bydrae.

(Get.) JAS. GRAY,

*Ere-Algemene Penningmeester.*

# THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
## BALANCE SHEET AT 31st MAY, 1943.

### LIABILITIES.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| **Sundry Creditors:** | | | | | | |
| General Accounts ... ... ... | £69 | 16 | 5 | | | |
| Grants to Local Centres under Rule 35 ... ... ... ... | 43 | 6 | 0 | | | |
| Recipient South Africa Medal Award, 1943 ... ... ... | 51 | 8 | 8 | | | |
| Subscriptions paid in advance | 11 | 11 | 0 | | | |
| | | | | £176 | 2 | 1 |
| **Library Binding and Equipment Account:** | | | | | | |
| Balance at 31st May, 1942 ... | 142 | 6 | 0 | | | |
| *Add*—Interest from Library Endowment Fund ... ... | 74 | 9 | 3 | | | |
| | 216 | 15 | 3 | | | |
| *Less*—Expenditure during year | 35 | 8 | 1 | | | |
| | | | | 181 | 7 | 2 |
| **Income and Expenditure Account:** | | | | | | |
| Balance at 31st May, 1942 ... | 659 | 5 | 10 | | | |
| *Add*—Excess of Income over Expenditure for the year ended 31st May, 1943 ... | 173 | 18 | 3 | | | |
| | | | | 833 | 4 | 1 |
| | | | | 1.190 | 13 | 4 |
| Endowment Fund ... ... ... ... ... | | | | 3.216 | 14 | 5 |
| Library Endowment Fund ... ... .. | | | | 2,164 | 11 | 6 |
| South Africa Medal Fund ... ... ... | | | | 1.670 | 9 | 1 |
| British Association Medal Fund ... ... | | | | 500 | 19 | 9 |
| | | | | £8.743 | 8 | 1 |

### ASSETS.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| **Cash:** | | | | | | |
| At Bank ... ... ... ... | £668 | 5 | 8 | | | |
| At Post Office Savings Bank, with Interest accrued ... ... | 38 | 18 | 6 | | | |
| At St. Andrew's Building Society, with Interest accrued | 432 | 17 | 8 | | | |
| | | | | £1,140 | 1 | 10 |
| **Sundry Debtors:** | | | | | | |
| Endowment Fund ... ... | 0 | 5 | 11 | | | |
| Library Endowment Fund ... | 4 | 9 | 3 | | | |
| South Africa Medal Fund ... | 0 | 2 | 3 | | | |
| For Reprints of Papers, etc. ... | 8 | 5 | 9 | | | |
| | | | | 13 | 3 | 2 |
| **Furniture:** | | | | | | |
| Balance at 31st May, 1942 ... | 42 | 9 | 6 | | | |
| *Less*—Depreciation ... ... | 8 | 10 | 0 | | | |
| | | | | 33 | 19 | 6 |
| Medals on Hand ... ... ... ... ... | | | | 3 | 8 | 10 |
| | | | | 1.190 | 13 | 4 |
| Trustees—Endowment Fund ... ... ... As per separate Account. | | | | 3.216 | 14 | 5 |
| Library Endowment Fund ... ... ... As per separate Account. | | | | 2.164 | 11 | 6 |
| Trustees—South Africa Medal Fund ... ... As per separate Account. | | | | 1,670 | 9 | 1 |
| Trustees—British Association Medal Fund ... As per separate Account. | | | | 500 | 19 | 9 |
| | | | | £8,743 | 8 | 1 |

We have examined the books, accounts and vouchers of The South African Association for the Advancement of Science for the year ended 31st May, 1943, and have obtained all the information and explanations we have required. We have satisfied ourselves of the existence of the securities. Proper books and accounts have been kept. In our opinion the above Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of affairs of the Association at the 31st May, 1943, according to the best of our information and the explanations given to us and as shown by the books of the Association as at 31st May, 1943.

Johannesburg, 17th June, 1943.

ALEX. AIKEN & CARTER, Auditors.

## THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

### INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1943.

**Dr.**

| | | | |
|---|---|---|---|
| To Secretarial Fees ... ... | | | £185 0 0 |
| ,, Journal Expenses ... ... | | £751 1 0 | |
| *Less*— | | | |
| Government Grant | £250 0 0 | | |
| Johannesburg Municipal Grant | 100 0 0 | | |
| Sales, Reprints and Advertisements | 170 19 9 | | |
| | | 520 19 9 | |
| | | | 230 1 3 |
| ,, Stationery and Printing .. | | | 48 6 10 |
| ,, Postages ... ... ... ... | | | 18 14 9 |
| ,, Expenses: | | | |
| Annual Meeting, 1942 ... | | 11 12 0 | |
| Annual Meeting, 1943 (on account) ... ... ... | | 0 5 0 | |
| | | | 11 17 0 |
| ,, Sundry General Expenses ... | | | 14 5 1 |
| ,, Grants to Local Centres under Rule 35: | | | |
| Witwatersrand ... ... | | 24 2 0 | |
| Cape Province .. ... | | 10 13 0 | |
| Natal ... . ... ... | | 8 11 0 | |
| | | | 43 6 0 |
| ,, Depreciation on Office Furniture ... .. | | | 8 10 0 |
| ,, Pension—H. A. G. Jeffreys .. ... ... | | | 90 0 0 |
| ,, Balance, being Excess of Income over Expenditure, for the year ended 31st May, 1943 ... ... ... ... ... ... | | | 173 18 3 |
| | | | £823 19 2 |

**Cr.**

| | | |
|---|---|---|
| By Annual Subscriptions ... ... | £563 0 6 | |
| ,, Arrear Subscriptions ... ... | 110 4 6 | |
| ,, Associates' Fees ... ... | 1 10 0 | |
| ,, Students' Fees ... ... ... | 1 5 0 | |
| | | £676 0 0 |
| ,, Interest: | | |
| From Endowment Fund ... | 137 8 5 | |
| St. Andrew's Building Society Account ... ... | 9 13 9 | |
| Post Office Savings Bank Account ... ... ... | 0 17 0 | |
| | | 147 19 2 |
| | | £823 19 2 |

We report that to the best of our knowledge and belief, and on the information supplied to us the above account reflects a true statement of the income and expenditure of the Association for the year ended 31st May, 1943.

Johannesburg,
17th June. 1943.

ALEX. AIKEN & CARTER,
Auditors.

# THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

## ENDOWMENT FUND.

### INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1943.

| Dr. | | Cr. | |
|---|---|---|---|
| To Interest, as per contra, transferred to General Fund .. ... ... .. | £137 8 5 | By Interest received during the year ... ... | £137 8 5 |
| ,, Balance, transferred to Accumulated Funds | 26 10 0 | ,, Life Membership Subscriptions ... ... | 26 10 0 |
| | £163 18 5 | | £163 18 5 |

### BALANCE SHEET AT 31st MAY, 1943.

| Liabilities. | | | Assets. | |
|---|---|---|---|---|
| Amount due to General Fund ... | | £0 5 11 | Investments in hands of Trustees— | |
| Accumulated Funds— | | | Cape Town Municipality 3¼% Stock ... | ...£1,150 0 0 |
| Balance at 31st May, 1942 | ...£3,190 4 5 | | Cape Town Municipality 4% Stock ... | ... 300 0 0 |
| *Add*—Amount transferred from Income and Expenditure Account ... .. .. | 26 10 0 | | Cape Town Municipality 5% Stock ... | ... 240 0 0 |
| | | 3,216 14 5 | Cape Town Municipality 5% Stock ... | ... 800 0 0 |
| | | | Port Elizabeth Municipality 3¼% Stock | ... 100 0 0 |
| | | | Cape of Good Hope Savings Bank ... | ... 627 0 4 |
| | | £3,217 0 4 | | £3,217 0 4 |

## THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

### LIBRARY ENDOWMENT FUND.

**Dr.** INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1943. **Cr.**

| | £ s. d. | | £ s. d. |
|---|---|---|---|
| To Balance, transferred to Library Binding and Equipment Account ... ... ... | £74 9 3 | By Interest received during the year ... ... | £74 9 3 |
| | £74 9 3 | | £74 9 3 |

### BALANCE SHEET AT 31st MAY. 1943.

| Liabilities. | £ s. d. | Assets. | £ s. d. |
|---|---|---|---|
| Amount due to General Fund ... ... ... | £4 9 3 | Investments— £2,000 City of Johannesburg 3½% Local Registered Stock, 1965—at cost ... ... | £1,970 0 0 |
| Accumulated Funds— Balance at 31st May, 1942 ... ... ... | 2,164 11 6 | Cash at St. Andrew's Building Society— Savings Bank Account ... ... ... ... | 199 0 9 |
| | £2,169 0 9 | | £2,169 0 9 |

## THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

### SOUTH AFRICA MEDAL FUND.

### INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1943.

| Dr. | | Cr. | |
|---|---|---|---|
| To Expenses in connection with 1943 Award ... | £6 19 10 | By Interest received during the year ... ... | £58 8 6 |
| ,, Amount of 1943 Award ... ... ... | 51 8 8 | | |
| | £58 8 6 | | £58 8 6 |

### BALANCE SHEET AT 31st MAY, 1943.

| Liabilities. | | Assets. | |
|---|---|---|---|
| Amount due to General Fund ... ... ... | £0 2 3 | Investments in hands of Trustees— | |
| Accumulated Funds— | | Fixed Deposit, South African Permanent Mutual Building and Investment Society ... | £1,666 0 1 |
| Balance at 31st May, 1942 .. ... | 1,670 9 1 | Post Office Savings Bank ... ... ... | 4 11 3 |
| | £1,670 11 4 | | £1,670 11 4 |

## THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

### THE BRITISH ASSOCIATION MEDAL FUND.

### INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1943.

| Dr. | | Cr. | |
|---|---|---|---|
| To Balance, transferred to Accumulated Funds | £17 9 6 | By Interest received during the year ... ... | £17 9 6 |
| | £17 9 6 | | £17 9 6 |

### BALANCE SHEET AT 31st MAY, 1943.

| Liabilities. | | | Assets. | |
|---|---|---|---|---|
| Accumulated Funds— | | | Investments in hands of Trustees— | |
| Balance at 31st May, 1942 ... | £483 10 3 | | £450 Union of South Africa 3¾% Local Registered Stock, 1948/58 ... ... ... | £450 0 0 |
| *Add*—Amount transferred from Income and Expenditure Account ... ... ... | 17 9 6 | | Post Office Savings Bank ... ... ... | 50 19 9 |
| | | £500 19 9 | | |
| | | £500 19 9 | | £500 19 9 |

# REPORT OF THE HONORARY LIBRARIAN FOR THE YEAR ENDED 31st MAY, 1943.

# VERSLAG VAN DIE ERE-BIBLIOTEKARIS VIR DIE JAAR GEEINDIG 31 MAY, 1943.

The Association's Library is housed in the Library of the University of the Witwatersrand, Johannesburg.

Die Genootskap se Biblioteek word in die Biblioteek van die Universiteit van die Witwatersrand, Johannesburg gehuisves.

HOURS OF OPENING/URE.

*Weekdays/Weekdae.* Term/Semester: 8.30 a.m./v.m. to/tot 6 p.m./n.m.
Vacation/Vakansie: 9 a.m./v.m. to/tot 5 p.m./n.m.

*Saturdays/Saterdae* Term/Semester: 8.30 a.m./v.m. to/tot 12.30 p.m./n.m.
Vacation/Vakansie: 9 a.m./v.m. to/tot 12.30 p.m./n.m.

EXCHANGE OF PUBLICATIONS.—During the year the following names were added to the exchange mailing list:—

RUILING VAN PUBLIKASIES.—Gedurende die jaar is die volgende name aan die ruilingsadreslys bygevoeg:—

Royal Society of New South Wales, Sydney, Australia.

Section of international exchange, All-Union Lenin Library, U.S.S.R.

Society for cultural relations with foreign countries, U.S.S.R.

DONATIONS.—In response to an appeal for back volumes of the *Journal*, volumes were kindly donated by the following:—

GESKENKE.—In antwoord op 'n beroep vir vorige bande van die *Journal*, is bande deur die volgende welwillend geskenk:—

Mrs./Mev. J. F. Solly. 4, 1907; 5, 1908; 14-20, 1917-23 incomp.; 33-36, 1936-39; 38, 1941.

Mr./Mnr. B. T. Mennell. 25-38, 1928-41.

Mr./Mnr. G. Ingham. 28-29, 1931-32; 35, 1938.

Prof. L. F. Maingard. 31-35, 1934-38.

SALES.—Part sets and back volumes of the *Journal* to the value of £32 6s. were supplied on orders received from the C.N.A., the F.W. Faxon Co., the School of Agriculture, Khartoum North, and Dr. L. H. Wells.

VERKOPINGS.—Gedeeltelike stelle en vorige bande van die *Journal* ter waarde van £32 6s. is gelewer op bestellings van die C.N.A., the F. W. Faxon Co., die School of Agriculture, Khartoum North, en Dr. L. H. Wells ontvang.

STOCK.—The Library now contains about 3,600 volumes, and 180 different titles are received currently.

VOORRAAD.—Die Biblioteek besit nou omtrent 3,600 bande, en 180 verskillende titels word lopend ontvang.

ACCESSIONS TO SERIAL PUBLICATIONS/AANWINSTE TOT PERIODIEKE PUBLIKASIES 1942/43:—

American Association for the Advancement of Science. Bulletin. 2, 1943+.

Monthly Science News. No. 10, May, 1942+.

For a Catalogue of serial publications in the Library, and Supplement, see this *Journal*, Vol. 30, p. xxv-xxix and Vol. 34, p. xxxiv-xxxvii. Subsequent accessions are listed in the Annual Report.

Vir 'n katalogus van periodieke publikasies in die Biblioteek, en Supplement, sien hierdie *Journal*, Band 30 bl. xxv-xxix en Band 34 bl. xxxiv-xxxvii. 'n Lys van latere aanwinste word in die Jaarlikse Verslag gegee.

P. FREER,
Hon. Librarian/Ere-Bibliotekaris.

## SOUTH AFRICAN CURRENT SCIENTIFIC AND TECHNICAL PERIODICALS RECEIVED IN THE LIBRARY OF THE ASSOCIATION.

Associated Scientific and Technical Societies of South Africa. Proceedings.

Bloemfontein. Nasionale Museum. Navorsinge.

Boerdery in Suid-Afrika. Farming in South Africa.

Cape Naturalist.

Chemical, Metallurgical and Mining Society of South Africa. Journal.

Geological Society of South Africa. Transactions and Proceedings.

Natal Museum. Annals.

Onderstepoort Journal.

Rhodesia Agricultural Journal.

Rhodesia Scientific Association. Proceedings.

Royal Society of South Africa. Transactions.

South African Chemical Institute. Journal.

South African Engineering.

South African Geographical Journal.

South African Institution of Engineers. Journal.

South African Institute of Electrical Engineers. Transactions.

South African Journal of Science.

South African Museum. Annals.

South African Sugar Journal.

South African Veterinary and Medical Association. Journal.

Union Observatory. Circulars.

Astronomical Society of South Africa. Journal.

# In Memoriam.

## THEODORE REUNERT, D.Litt., M.I.C.E., M.I.M.E.

Dr. Reunert was born in Leeds in 1856 and died in Durban in the house of his son Mr. P. J. Reunert on the 21st January, 1943, at the age of 86. He served an apprenticeship in mechanical engineering in Leeds and received his education in the Yorkshire College of Science, now the University of Leeds. He came to South Africa in 1879 and settled in Kimberley, where he practised as an engineer for about 10 years; he removed to Johannesburg in 1888, establishing the firm of Reunert & Lenz in partnership with the late Mr. Otto Lenz.

Dr. Reunert was one of the principal workers both before and after Union for the provision of university, technical and secondary education in the Transvaal, and one of the leading representatives of culture in Johannesburg.

In 1891 he became one of the founders of the South African Association of Engineers. In 1895 a Council of Education was formed, and of this Dr. Reunert was one of the original members and chairman for several years. His connection with the Association for the Advancement of Science is best described by the following extracts from Professor John Orr's presidential address at the Fifteenth Annual Meeting in July, 1917, viz:—

> "In July, 1901, a meeting at Cape Town called on the initiative of Mr. T. Reunert decided upon an annual congress of engineers. After further discussion, it was decided to enlarge the scope and form an association on the lines of the British Association, i.e. that a congress should be held annually at various centres . . . to cover the various branches of scientific and technical knowledge." "In June, 1902, there were 268 foundation members. . . . the Transvaal, Orange Free State and Natal being directed from Johannesburg, while to Cape Town were allocated Cape Colony, Rhodesia and the rest of South Africa. To Mr. Reunert and Dr. Gilchrist, who undertook the pioneer work as honorary secretaries at these respective centres, must be accorded the unstinted praise of our Association."

Dr. Reunert was a foundation member and an honorary life member of the Association, and president of the Association during the visit of the British Association in 1905.

His great interest in technical and university education was already recognised in 1902 when he was a member of the committee appointed by the Transvaal Government for the consideration of technical education. This committee reported in 1903, and a Commission—including Dr. Reunert—was then appointed to consider and report on university education. The Transvaal Technical Institute was established as a result of this Commission's work and Dr. Reunert became a member of the first Council of the

Institute. Later when the University of the Witwatersrand was established he became a member of the University Council.

In 1905 he was a member of the Transvaal Government's Secondary Education Commission which resulted in the foundation in Johannesburg of three High Schools, viz., the Johannesburg High School for Girls, King Edward VII. School and the Jeppe High School. During the whole of the period 1907-1915 when a Government Council of Education was in existence in conformity with the Smuts Education Act, Dr. Reunert served as a member. He also took part in the formation of the South African Lectures Committee, which arranged for the lecture tours in South Africa of the Right Hon. H. A. L. Fisher, Professors Thomson and Balfour and Sir Walter Raleigh. He was also for several years chairman of the old Subscribers' Public Library. In 1922 the University of the Witwatersrand conferred upon him the Honorary Degree of D.Litt. in recognition of his life-long services to education and culture.

Dr. Reunert was married and had four sons, his wife dying in 1921, and three sons now surviving.

---

## THOMAS NICHOLAS LESLIE, D.Sc., F.G.S., F.R.Met.S.

---

Thomas Nicholas Leslie was born at Nottingham in England in 1858 and died at Vereeniging in South Africa on the 5th September, 1942, in his 84th year. At an early age he suffered the loss of both his parents, and, leaving school at eleven with only an elementary education, he was compelled to earn his own living and found employment in a brickworks. He was later apprenticed to a builder. In 1881 he left England to come to South Africa, where he was employed in building construction at various places. When he had saved up the amount of £150 he made up his mind to see the country thoroughly, and so he stopped work, bought a horse and travelled about until his savings were exhausted. He then spent some years in Pretoria, but in 1892 went to Vereeniging to erect new buildings for the coal mine and brickworks and there he settled down. Vereeniging in those days was a very small place, but with its valuable natural resources it commenced to grow rapidly. Dr. Leslie was very closely connected with its development and is looked upon as one of the founders of this now very important town. He was a member of the first local government body, the Health Board, constituted for the town. When owing to the growth of the town this was replaced by an Urban District Board he was a member of that body and became its chairman. When Vereeniging was proclaimed a municipality he was on its Council and was the Mayor of the town from 1904 to 1917 and again from 1926 to 1929. He was also elected president of the Transvaal Municipal Association on two separate occasions.

He took a great interest in educational matters and was instrumental in founding the Selborne School at Vereeniging, of whose committee he was chairman for 30 years. He was also on the governing body of King Edward VII. School. He was on the Technical College Council and opened the Technical College at Vereeniging. He founded the first Public Library for Vereeniging, actually starting it in a room of his own house and mainly with his own fine collection of books.

Municipal government and educational matters, however, did not represent by any means all his activities. He was deeply interested in the natural sciences, and in particular made extensive collections of fossil plants found in the vicinity of Vereeniging. He also collected and cultivated the succulent plants of South Africa. He discovered a most interesting window-plant, Lithops Leshei, and another striking succulent plant, Argyroderma Lesliei, was named in his honour. His interest in botany and paleobotany brought him into contact with overseas authorities on these subjects, such as N. E. Brown of Kew and Professor Seward of Cambridge.

Dr. Leslie made a fine series of photographs, exactly to scale, of South African succulent plants, and his photographs have been used to illustrate many works on botany. The excellence of his plant photographs was recognised when a display of them at the Empire Exhibition at Johannesburg in 1936 was given an award by the Johannesburg Photographic Society. He also made an excellent series of photographs of clouds and lightning flashes, and was very successful in photographing the spectrum of lightning. Frequent reference to Dr. Leslie's scientific work is to be found in many text-books, and the conferment upon him of the honorary degree of Doctor of Science by the University of the Witwatersrand in 1931 was well merited. He was an active member of the South African Association for the Advancement of Science, joining it in 1903 shortly after its inception. In 1926 he was vice-president of the Association, and in 1929 he represented South Africa as vice-president of Section C of the British Association during their visit that year. The Association further honoured him by election to an honorary life membership. He was a very prominent member of the Geological Society of South Africa, serving on the Council for many years and being president in 1921.

Dr. Leslie led a very full life for his interests were many. He also possessed the ability to inspire others with his love of nature, and many people owe a greater interest in life to his influence. It may well be said of him that the world was richer for his presence.

H. E. W.

# In Memoriam.

## THE REV. WILLIAM FLINT, D.D.

On the 18th February, 1943, the Rev. Dr. William Flint, a foundation member, life member and past president of the Association, passed away at his home in Rosebank, Cape Town, in his 89th year.

Dr. Flint was born at Stanbridge, Belfordshire, in 1854, was ordained to the Ministry of the Wesleyan Methodist Church in 1882 and held a number of appointments in England until his health failed in 1889 and he came to South Africa. Here he served at Colesberg, Maritzburg and Cape Town and finally settled at Rosebank, where he spent his life. In 1892 he married Miss Margaret McGregor, daughter of Alexander McGregor of Rondebosch and Kimberley, and is survived by his wife and five children, to whom the sympathies of the Association are extended.

In 1896 he founded and became the first editor of "The Methodist Churchman," and he established the Methodist Theological College at Mowbray, of which he was Honorary President until it was closed in 1939. In 1901 he was appointed Librarian of Parliament, a post which he held for 20 years. From 1903 to 1907 he was editor and co-editor of the Journal of this Association, became president of Section F in 1910 and president of the Association in 1919. The Royal Society of South Africa and the British Association also claimed him as a member.

Intensely interested in educational matters, he served for 33 years as a member of the Council of the University of the Cape of Good Hope (later the University of South Africa) and as Examiner, was a member and at one time chairman of the Huguenot University College and one of the founders of the Rondebosch Boys' High School. Dr. Flint was a co-editor of "Science in South Africa," editor of the "S.A. Science Reports," joint-secretary for the Inter-Colonial Conference on University Education in South Africa, member of the Archives Commission and author of "Archives as a National Asset," "Some Financial Features of the Canadian Educational System," and "The Legal and Economic Bases of Some Colonial Teaching Universities."

By many Dr. Flint will ever be remembered for his charming personality, his versatility, his sympathy with humble causes, his courage and the many services he so readily and cheerfully rendered to the public. Within the Association his happy presence, interest in the problems of education and wise counsels will be greatly missed.

A. L. D. T.

# In Memoriam.

## WILLEM HENDRIK LOGEMAN, M.A.

A son of Professor W. S. Logeman, who was Professor of Modern Languages at the South African College (now University of Cape Town), Professor Logeman was born at Rockferry, England, where his father taught before coming to South Africa. After studying at Cape Town, where he took the M.A. degree, he went to Cambridge, where for three years he was a research student and worked under Sir J. J. Thomson in the Cavendish Laboratory. On returning to South Africa he took the place of Sir Carruthers Beattie at the South African College for one year. From Cape Town he went to Bloemfontein as Professor of Physics in Grey University College (University College of the O.F.S.), where he taught for 27 years. He died at the comparatively early age of 61.

Professor Logeman was a clear and interesting lecturer, both to his own students and to general audiences in the many extension and other lectures which he gave outside the College. He was hampered in his work at Bloemfontein through want of adequate assistance, laboratory space, and equipment, but he succeeded in overcoming the main difficulties and in inspiring his students with his own interest in scientific research. He was an expert designer and maker of scientific apparatus of various kinds, and spent much time in his workshop supplying the most necessary equipment for his department. He represented the Senate of G.U.C. for some years on the Council, and in this capacity did excellent work for the College and for his colleagues.

Professor Logeman joined the South African Association as early as 1903. He was a life member of the Association, President of Section A at the Bloemfontein meeting in 1923, and he gave the Evening Discourse at Bulawayo in 1911 (on the gyroscope). His untimely death is mourned by a large circle of friends and colleagues.

T.M.F.

## BERTHA STONEMAN, D.Sc., Ph.D.

In the passing of Dr. Bertha Stoneman South Africa has lost not only one of her pioneer botanists but a true South African who adopted this country as her own and spent nearly half her life working in its educational interests.

A farmer's daughter, born at Jamestown, U.S.A., on the shores of Lake Chautauqua, in August, 1866. Dr. Stoneman early showed exceptional mental ability. She graduated at Cornell University, where she obtained

her D.Sc. and Ph.D. In 1897 she came to South Africa as Lecturer in Botany to the newly established Huguenot College for Girls at Wellington—came for 1 year and stayed 36. She at once became absorbed in the study of the Cape flora and spent her free time scouring the mountain sides for plants, with which she built up a substantial herbarium. By dint of hard work and perseverance she gradually overcame all obstacles and succeeded in establishing botany at Huguenot on a sound footing. She soon became an authority on South African botany, and in 1906, at the request of the Education Department, published the first edition of her book "Plants and Their Ways in South Africa," which for many years was used in schools at the Cape. To Dr. Stoneman botany was a living subject and she imbued her students with her enthusiasm. From her lectures a band of graduates went out qualified to take up responsible posts, social as well as academic, throughout the length and breadth of the land.

In 1921 Dr. Stoneman succeeded Dr. Bliss as president of the Huguenot University College. Never very strong and already overburdened with the responsibility of the Chairs of both Botany and Philosophy, she nevertheless took on the additional administrative and social duties. The strain, however, proved too great, and she was reluctantly obliged to relinquish the botanical work. She retired in 1933. It was her intention to settle in the United States but, after a short visit, she realised that South Africa held most of her friends and interests and she returned to this country. Here she remained at Bainskloof, where she had recently built a home and was living with a former student who did much to brighten the last years of her life. She passed away on 30th April, 1943.

Keenly interested in science, philosophy and student life, Dr. Stoneman at one time took an active part in many scientific and academic organisations. In 1905 she became a life member of the Association for the Advancement of Science, frequently taking part in the Annual Congresses and serving as president of Section C (Botany) in 1923; she was also the first president of the South African Association of University Women.

Dr. Stoneman will be remembered not so much for her published work as for what she did in the interests of the higher education of women in South Africa. Through her influence and help many students received the benefits of a university education. By them she will always be remembered with affection for the personal interest she took in their welfare. Kindly, unselfish and generous, no appeal for assistance ever fell on deaf ears. Dr. Stoneman's absorbing interest to the very end was the Huguenot University College, and for it she sacrificed time, money and health.

A. M. B.

# In Memoriam.

## BERNARD DE COLIGNY MARCHAND, D.Sc., B.A.

Dr. Marchand, chemist to the Department of Agriculture, Division of Chemistry, became a member of the Association at the Annual Meeting in Pretoria in 1915. A few years later he contributed the first of many papers to the proceedings of the Annual Congress and was president of Section B in 1925. In 1922 he became a member of the Council of the Association and served in that capacity in Johannesburg, Pretoria and Cape Town in succession at various times for 12 years until his death on the 19th December, 1942, at the comparatively early age of 57, following an emergency operation.

Dr. Marchand received his education at the University of Edinburgh, where he graduated as D.Sc. On his return to South Africa he entered the Agricultural Department of the Union Civil Service and specialised in agricultural chemistry, in which he rapidly became a recognised authority on questions affecting soil fertility, particularly in the domain of the physical properties of soils, and he contributed a number of papers on this subject to the Association's proceedings.

It is through his work on "The Sticky Points of Soil-Water Mixtures" that the contacts made by correspondence with overseas agricultural research workers, such as those at Rothamstead and in Ireland developed at the joint meeting of the British and South African Associations in 1929 into friendly co-operation in the solution of common problems.

Requirements of the Government Service led to his transfer from Pretoria to Cape Town in 1925, and some years later to a return in order to take charge of the Government Chemical Laboratories at Johannesburg, and finally to his return to Cape Town. Dr. Marchand was an outstanding chemist, and exercised a marked influence on the work of the Government institutions with which he was associated. No one could come in contact with him without being impressed by his ability, by his obvious sincerity and by his determined championship of what he held to be right. In his spare time he read widely and well,remembering clearly and often quoting accurately from his reading many years before.

This tribute would be incomplete without a reference to his great knowledge of Afrikaans, on which subject he was regarded as an authority. He was particularly active in the translation of old documents belonging to the days of the Transvaal Republic, and was associated in that respect with Mr. and Mrs. Gray in their historic work on the discovery of the Witwatersrand Goldfields.

His loss has been deeply felt by his friends and in scientific circles in this country and overseas. His widow and daughter survive and to them the sympathies of the Association are extended.

G.F.B.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 1-14, November, 1943.*

# THE FILM IN BIOLOGY

BY

DR. A. PIJPER,
*President.*

*President's Address delivered 28th June, 1943.*

Tradition demands that a presidential address shall appeal to a wider circle than one's own professional colleagues, and at the same time reflect some of the professional activities of the president. Now I am a registered medical practitioner and my profession is medicine, but I am quite sure that when you did me the great honour of electing me president, you did not expect me to address you on the subject of human ailments.

Medicine to me is a branch of biology, and as we all go to the bioscope at times, it seemed to me that the subject of The Film in Biology would meet the requirements of a proper presidential address. Moreover, I take a great, or even an active interest in biological films. I believe in the future of the film in biology, so much so that I'll venture to make a prophecy here and now. I expect that very soon presidential addresses by biologists, and probably also by other scientists, will take the form of sound films. Audiences expect more and more not just to listen, but also to see. By then, of course, we shall have to invent a new term, for it would never do to announce that on such and such a date the president will deliver his presidential "talkie;" we shall need a more solemn word. The film is a new international method of publication and communication in biological matters, comparable to the formula in mathematics and chemistry. It will become the method of choice in education, and it will also serve as a new research method.

My chosen subject has not much of a history. This is an advantage. June and July are uneasy months for ancient scientists, on account of the many scientific congresses held during that period. I don't mean that they keep on revolving in their graves on account of the heresies that we commit. I mean that so many presidential addresses have to trot out the ghosts of Aristotle and Newton to get going. Be reassured, no such ghosts are walking to-night. We need not go back far for the originators of filming, many of them are still with us, and anyhow, I am more interested in the future than in the past.

But it is noteworthy that filming had its origin in biological curiosity. Does a galloping horse ever have its four feet off the ground at the same time? That was the somewhat trivial

problem that Muybridge, an American, solved in 1872, by putting twenty-four ordinary cameras in a row and making a horse gallop past. The horse itself, in passing, by means of stretched wires worked the shutters. The result was perhaps not quite a film, because it was not meant to be projected, but as it eventually was, we may put down the seventies as the birth years of the film. In Muybridge's work then we already have the two elements that make a film: analysis by a rapid succession of photographic pictures, and a suitable synthesis of the pictures on a screen. An American engineer named Heyl, had designed a projecting apparatus in 1870. But it should not be forgotten that the idea on which the projection of a film is based dates from Roget. Roget, an Englishman, showed in 1824, that the human eye remembers a picture for a short time. A series of pictures of motion, presented to the eye in chronological order at the rate of about sixteen per second, therefore, give the impression of continuous motion. This idea by itself gave rise to the production of the kind of peepshows that some of us remember as penny-in-the-slot machines at seaside places, and these were in a sense the humble precursors of Walt Disney's brilliant work, for they showed a series of continuous drawings, not of photographs.

Such then are the foundations of all film work. I shall not weary you with details of further developments. How the twenty-four cameras became one camera, how Edison put the photographic pictures on a belt, how Eastman invented the now so common photographic film, all that makes a long story of which I must leave out details. Further improvements followed, connected with various names, amongst whom the Lumiere brothers should be specially mentioned. If you want further dates, let me say that round about 1900, film making and projection were in principle more or less established as we know them now. Important technical improvements have since been added to the various processes, and sound films and colour films have come in, but the last two items are not even regarded as improvements by everybody. As a form of entertainment, the film has risen to great heights, but its use in science has not been so phenomenal. There are few books on my subject and overseas channels of information being more or less blocked at the present time, I can only give you a scrappy idea of the progress of scientific films.

Life being movement, biologists must have been attracted by the new method of recording and reproducing movement. It seems that Dr. Braun of Vienna, filmed the moving mammalian heart in 1897, and in the same year Schuster of Berlin, filmed the abnormal gait of patients. The next year, 1898, saw the filming of the first surgical operation by Doyen, the famous French surgeon. Doyen wanted to study the movements of his own hand, but a dispute arose as to the ownership of the film and it ended its life as a sideshow at village fairs

and markets. And so we shall never know whether it was true what some people said, viz.: that Doyen had himself filmed in what novels called faultless evening dress. I do not believe it. But Doyen's film efforts were not popular with his colleagues, and the work was discontinued. Strange to say, very little use was made of the film for purely scientific purposes in the first twenty years of this age. This should make our admiration all the greater for the few workers who had vision and realised the possibilities. I shall just mention Comandon, in Paris, who was the first to attach a film camera to a microscope in 1909, and made microcinematographic pictures of microscopic objects that are supposed not to have been excelled to-day. Between 1920 and 1930, more biological work was done with films, but the chapter in Abderhalden's "Handbuch der Biologischen Arbeitsmethoden" dealing with the subject in 1931, is only just twenty pages long, of which microcinematography gets a few pages only. As there seem to be no comprehensive books of a later date, it is difficult to assess what has been done since. One has to fall back on occasional papers in scientific journals of various kinds, and then there is an important source of information provided by booklets published by firms that deal in apparatus for the purpose. It is not easy to keep track of these publications, and the respective journals are often difficult of access. My search left me with two impressions. One is surprise at the splendid work that has here and there been done on biological scientific films, and the other is disappointment at the lack of co-operation, both in the work and in the distribution of the films. There are obviously many excellent films that hardly ever see the light of the projector.

The word projector reminds me that I have rather barged into my subject without much explanation. As there must be many potential film makers amongst you who have abstained from active participation on account of supposed technical difficulties, it will be profitable to go into technical matters for a bit.

It is startling, but true, when I say that in many ways it is easier to make films than still photographs. But, to produce really good films is at least as difficult as to produce excellent still photographs. The camera never lies, but it also never forgives, and no photographic picture is ever better than it should be. It follows that the first ingredient in the turning out of good films is endless patience. Don't start without that. The next essential requirement is a capacity for self-criticism. As my friend Dr. P. J. du Toit once said: "most research consists of failures," and so it is with most scientific films. Apart from occasional lucky shots, one must be prepared to throw away reels and reels of film that are not quite up to standard. There is no other road to success, and this should be realised from the start. Biological objects are stubborn and wayward creatures,

of unpredictable conduct, compared to which the moods and whims of Hollywood actresses are insignificant. Also, the combination of place, time and the loved object is often difficult to realise. One should never start on a film unless conditions are perfect, but human nature being what it is, one often does. It is all these factors that necessitate such severe self-criticism before one may show one's films to the world.

Considering then our own imperfection and that of the biological material to be filmed one should at least aim at having the best possible equipment. Imperfect cameras will always jam at the least suitable moment. The camera should accommodate at least 100 feet of film, to avoid unnecessary delay in changing spools, for biological events do not abide our pleasure. The changing of spools should be easy and quick, for the same reason. Lenses should only be used for what they are intended, and their capacity goes up with their price.

The controversy as to which size of film is the most suitable for scientific filming can now be regarded as settled in favour of the 16 millimeter film. We can leave the 35 millimeter film to the professionals who have to fill the screen in halls seating thousands of people. Scientific audiences hardly ever exceed a hundred or two and can use a screen that is well covered by a 16 millimeter film. The 8 millimeter film is usually regarded as the size for the amateur, let us say for family use. The 16 millimeter film is perfectly suitable for the most difficult scientific work and has the advantage of costing only about a quarter of the 35 millimeter or professional size. Also, it is so much lighter that it can be moved through the camera at any speed by a wound spring, and the camera remains light enough to be handled with ease in situations which preclude the use of the 35 millimeter camera. Especially with the extremely good highly sensitive films that have been put on the market in recent years by the leading firms, especially by Kodak, one cannot do better than use a 16 millimeter camera for scientific work. The price of these films is high, but it includes developing or as it is technically called, processing, which is a good thing as it prevents one from having a try at it oneself, which usually ends in a mess. I think everybody nowadays uses so-called positive film, which produces a positive picture straight-away, without the need for changing a negative into a positive by copying onto another film.

A hundred foot reel of film, which at the usual speed of sixteen pictures or frames a second, takes four minutes to run through the camera, costs nearly two pounds. This works out at 2d. a second, and with the wastage that is unavoidable in filming biological objects, even with the best technique, the costs may become very considerably higher. This high cost is the reason why so many laboratories fight shy of employing film cameras. But the high cost of buying the film is, of course, very largely offset by the prolonged use that one can get out

of a film once it is made. Of a good film a copy, or as it is technically called, a duplicate, should be made at once, again, I admit, a rather costly procedure, but in this way the life of a film and the pleasure and use one gets out of it is extended nearly indefinitely. With proper organisation the demand for good films is bound to increase and a market might be created in which duplicates could be sold at a little over their cost price so as gradually to pay off the original outlay. There is already at least one scientific institution in Germany that works along these lines.

To come back to the camera, for microscopic work one does not need a camera lens. It is replaced by the eyepiece of the microscope and there are firms that will allow one to buy a camera without a lens, which usually about halves the purchase price. Also, it is not necessary to buy a camera with all possible gadgets. What is called "dissolves" and "fading out" and "fading in" may be very effective for entertainment films, but they are certainly not essential for scientific work. What is essential, however, are devices for higher speeds than sixteen pictures a second and for what is called a "single picture mechanism." These require some explanation. Richet once said that the cinema had made us master of time and place. The cinema makes it possible to witness events that have taken place miles away, we all know that from the news reels in the bioscope. The same of course is done in science. How does the cinema make us master of time? The cinema enables us to show a phenomenon at its own speed, but also at a much higher or at a much lower speed. We can condense an event in time, or draw it out. The first is called time-lapse, and the other slow motion. If one films an event at the usual speed of sixteen pictures a second, and shows it on the screen at the same speed, everything happens on the screen at normal speed. But if one films a very fast phenomenon at a speed of say sixty-four pictures a second, and projects it on the screen at sixteen pictures a second, the screen shows the happenings slowed down four times, and one has four times as long to study the events. This is slow motion and its application to scientific phenomena has made the cinema camera into a research instrument of which we only begin to see the possibilities. Slowing down phenomena four times is not really much, very much more has been achieved, but it suffices for many biological observations.

Very slow biological phenomena, of which growth is a good example, often are too tedious to watch, and at any rate, nobody could keep on observing and recording for consecutive days and nights on end. A cinema camera with a single picture mechanism combined with a suitable clockwork can be set to take one picture, say, every minute. If the resulting film is projected at normal speed, on the screen things will appear speeded up about a thousand times, and the events of several days are

condensed into a few minutes. This time-lapse method again, converts the film camera into a research tool of nearly unlimited possibilities, as every biologist after a moment's thought will realise.

These then are the reasons why a film camera to be used for biological purposes should be equipped with varying speeds for the movement of the film and also with a single picture mechanism.

Everybody who makes films must of course have a projector to inspect his products on the screen. I am afraid that my admiration for the modern type of film camera does not extend to the usual type of film projector. I admit that the good ones throw magnificent pictures on the screen, but they are difficult to manipulate, one is never free from anxiety that something won't go wrong or break or slip, or burn out, and the machine costs about as much as a motor bicycle and often makes nearly as much noise. The apparatus is usually not capable of showing still pictures satisfactorily, and this precludes the close inspection of details of photography, often essential in scientific films. On all projectors used for biological scientific films, facilities should be present for reversing the film, as it is often instructive to trace the development of a phenomenon through all its phases by making a film run backwards. And perhaps the makers of projection apparatus will one day provide an attachment which will allow a short strip of film to be shown several times in succession without it having to be threaded into the apparatus every time. One often has short lengths of film which cannot be judged in any other way.

And this brings me to what is called the editing of a film. Few people are aware of the amount of thought and labour that go into the actual putting together of a biological or any other film. It rarely happens that one can take pictures in the sequence in which they ultimately appear on the screen. Scenes go wrong, material is not available at the moment, there are all kinds of disturbing influences. As a rule after several months of taking shots, one finds oneself with a collection of parts which must then be fitted together in orderly sequence. Here that capacity for self-criticism comes in. Much film must be sacrificed, and many scenes that are not up to standard are to be retaken. Orderliness must grow out of chaos, and many days often have to be spent before the desired results are achieved. This is the time when titles have to be thought out and designed and put into place. The quality of a film as a whole largely depends on the care with which this editing process is undertaken. As to titles, for scientific work they should be simple and short, without frills. A film that requires long titles condemns itself.

I shall not go any deeper into the technical side of cinematography. What I have told you may give some indication of the work involved, and that, given good equipment,

the difficulties are not unsurmountable, provided one possesses patience and judgment. There are still large fields in biology to be explored with the film camera.

Before we go into what has already been done, it should be made clear what the applications of cinematography in biology really are. These are twofold. One is: demonstration, instruction or education. The other is: analysis, investigation or research. Everybody admits that films as a method of demonstration may serve education, but the conception of cinematography as a research method of its own, sometimes creates surprise. Of course, the two applications merge into one another, what is a matter of research to-day is the subject of a demonstration tomorrow. Biology being the science of living things and cinematography being the perfect method for recording movement, one would expect that biologists would have taken up cinematography. Such, however, has not been the case for many years, and only recently there are signs of a growing interest. My aim to-day is to stimulate this interest. Let me deal with the teaching or demonstration aspect first. In 1941, "The Lancet," the famous medical journal, in discussing a new film on malaria, which seems to have been everything that could be desired in scientific filming, went on to say: "The cinema film can be used to convey clearly to every member of an audience the details of almost any biological process, but academic circles in England have hardly noticed this new weapon." I have heard it stated somewhere else that some university teachers refuse to use films because their introduction would make lectures too much of an entertainment. This, of course, cannot be the sole nor the whole argument, there must be other reasons why more films are not made and used, but the contention is worth examining. We all know that teaching and learning means repetition. Things have to be hammered into our skulls, they don't enter like a flash. Most so-called teaching films are too much like a flash, they go past one like a dream, nobody can retain much at that speed, leave alone digest. So-called scientific biological films one occasionally sees in the bioscope often suffer from the additional defect of being too spectacular, the makers too readily succumb to the temptation of sacrificing instruction to impressing the audience. Cinematography will only get into its own as a teaching method when films become more leisurely, when the makers will find attractive ways of repeating the same information over and over again, or failing that, when teachers have the courage of showing the same film several times, till it is all taken in. Courage will be required for this, for audiences have been brought up to expect novelty in a film every time. There are, of course, occasions where the film merely serves as illustration, as an addition to the spoken lecture. But I think that properly made and properly used, the film can, with great advantage take over a good deal of ordinary teaching.

There is, to begin with, the advantage that the demonstration as given by the film, cannot go wrong. The film also can show selected material, not just what has haphazardly got into the hands of the teacher. In the teaching of biology, this makes the lecturer independent of the actual season, independent of the locality, independent of time. And then there is the added gain that the pupil sees everything through the eyes of the teacher. He gets " the angle " of the man who made the film and naturally that is the angle from which most is seen. In my own profession I had this brought home to me quite recently. The demonstration of skin diseases to a class of students is unsatisfactory, because the lesions show their characteristic features only when they are viewed from a particular angle and when light falls on them in a particular way. At the Pretoria Leprosy Hospital, Drs. Murray and Davison, have recently made a colour film of the dread skin disease we call leprosy. Both are experts on the disease and Dr. Murray is a very skilful cinematographer and the resulting film is a model of what a demonstration of such cases should be. In medicine the applicability of the film as a superior demonstration method does not end with skin diseases. I have for instance, also recently seen a colour film on fluorosis, the chronic poisoning caused by drinking water which affects one's teeth and one's bones, another production of Dr. Murray together with Dr. Ockerse, and this film again showed to perfection the curious lesions of the disease.

In surgery, teaching is handicapped because very few students can ever watch an operation so closely that they derive any profit, even if the interests of the patient did not forbid the close proximity of many persons. It is true that Doyen's first efforts at filming operations failed, but since then colour film has come in, and that has changed the whole outlook completely. In America numerous films have already been made, in natural colours, of various surgical operations and are used in daily teaching. Perhaps one should not speak of natural colours yet, and I fully appreciate the witticism of the man who said that colour films could only then be called perfect when nobody would notice that they were colour films, but there is no denying that the advent of colour films has made demonstrations possible that were quite impossible before. Modern medical appliances enable us to examine inner organs by direct inspection, such as ophthalmoscopes, cystoscopes, gastroscopes, etc. Naturally only one person at a time can have a look. The rapid glances occasionally allowed to students are now being replaced by the screening of colour films, and here again you will agree that the cinema has made us masters of time and place. The nasty remark once made about the science of medicine, that it had now progressed so far that the same patients could be used over and over again is true in a sense, but it also means that some diseases are nowadays cured so quickly that it is not always feasible to have suitable cases of a particular affliction available for demonstration, or

even, believe it or not, that some diseases are dying out or disappearing so quickly that they can hardly ever be demonstrated at their proper place in the course. Here again the colour film steps in and fills gaps that would otherwise have occurred.

There are already films in existence which depict the abnormal behaviour of mental patients much better than words can ever describe them, and here again it must be remembered that not every teaching institution can produce, for the student's benefit, at a moment's notice, the typical cases required in the course of teaching. First aid classes overseas have derived great advantages during the past few years from specially prepared films which made them familiar with the various lesions that may occur as the result of bombing and fire.

It is customary to regard X-ray pictures as something static. This is not correct as valuable information can often be gained by studying the shadows of moving organs on a fluorescent screen which is activated by X-rays. Here again the actual screen can only be seen by one or two persons at a time. Recently, however, it has proved possible to film the pictures on the fluorescent screen and thus make them available to a whole audience. The latest development is that some workers in Brazil have succeeded in making slow motion pictures of the moving heart as thrown on the fluorescent screen by X-rays.

The field for the development of cinematography in medicine and allied teaching is well nigh unlimited. Many progressive business firms such as Bayer, have for years used films to advertise their wares. There is already a film on the production and testing and application of the famous new sulfonamide drugs, made by the Lederle firm.

Coming nearer home and dealing with somewhat simpler subjects, the efforts of several South Africans to use the cinema camera for biological records and biological teaching should be remembered. There could hardly be a more impressive presentation of the dire results of neglect, overstocking and bad management of rainfall and other factors on South African farming than the splendid film of Mr. van Rensburg. I am also thinking of the memorable film of the flora and fauna of Africa, which Dr. Pole Evans brought home from one of his tours. And then there is the collection of films on insect life which Dr. Smit of the department of Entomology is building up with so much foresight. Our Department of Public Health has done its share by making available a number of films on public health matters. Working all by himself Dr. Nelson, Medical Officer of Health of Pretoria, has produced a very instructive film on the spread of plague. My list of South African efforts is by no means complete, there probably are many more locally produced biological films in the country, of which I have never heard. Especially for the teaching of natives, films on subjects like elementary hygiene must be invaluable and the Governments of Central African countries

are using travelling bioscope shows for the purpose. In South Africa itself, a good deal of the growing enthusiasm for filming, biological and otherwise, and especially for teaching, is certainly due to the untiring efforts of Mr. Beyers, the head of the Film Division of the Union Education Department, who has made a real success of the undertaking entrusted to him, and to the farsightedness of Dr. Gie, who was Director of Union Education when the Film Division was first started. The Division supplies thousands of films every year to our schools, many of them biological.

In other countries more and perhaps bigger and more advanced things have been done. In the biological field, Britain was fortunate in having its pioneer trio, Mr. Durden, Miss Field and Mr. Smith who are responsible for the well-known series of " Secrets of Life " films. I don't know whether these films have ever reached South Africa, but the still pictures I have seen of some of them filled me with admiration for their beauty and clarity. I always wonder why we do not get more of such films on our bioscope programmes. It cannot be that the public is not interested. The experience of the Pretoria Technical College Bureau for Adult and Visual Education, which has, under the able guidance of Mr. Lounsbury for years brought good biological films before the public, is against such a view.

I have come to the conclusion that this relative neglect of biological films for educational purposes which we find in so many places where one would not expect it, is largely due to lack of organisation. There are numbers of good films, but their distribution is not properly organised. There is an army of film makers, but it is an army fighting without headquarters. Their products could be compared to the books of a library scattered over the whole world, but without a catalogue and without an index.

In preparing this address I have done my best to collect information about biological films in existence in other parts of the world. This proved exceedingly difficult, and not just as a result of war conditions.

Sources of information about scientific films are few, and especially older films are difficult to trace and much good work seems irretrievably lost. An ambitious effort made by the Italian Government in 1928, to bring order into chaos by establishing an International Institute of Educational Cinematography and a Film Encyclopaedia came to very little, except that through the League of Nations which arranged an international conference at Geneva in 1933, the international exchange of educational films became facilitated. In England in 1936, there appeared a National Encyclopaedia of educational films, which of course, is not up to date now, and then there is the British Film Institute which prepares catalogues of teaching films, many of which are biological, and also edits two journals, the " Monthly Film Bulletin " and " Sight and Sound." Kodak

has its own catalogue of scientific films. In America, there are libraries of scientific films. The Journal of the Biological Photographic Association contains many references to biological cinema work and a good deal of information can also be gained from another American publication called "The Blue Book of non-Theatrical Films," which is brought out every year. Most excellent work has been done and is still being done by the British Association of Scientific Workers, through its very active Scientific Film Committee. This committee has now for five years been bringing out graded lists of scientific films and for this purpose it views about ninety films a year, many of them biological. It held a conference in London, in 1942, in co-operation with other bodies interested in scientific films, and they agreed that at least in Britain a totally inadequate use is being made in medical education of slow motion and microcinematography. The conference decided to set up a National Scientific Film Federation to co-ordinate efforts and to undertake the national planning of making scientific films.

At an exhibition recently held in London, again by the Association of Scientific Workers, on the application of photography to research problems, the number of scientific films was very small. If one excludes the more simple biological films that are suitable for the schoolroom, the number of biological films is apparently not very great. One reason probably is that more advanced biology requires microscopy, and filming through a microscope is not easy. A fair number of scientific biological films can very largely be taken in the ordinary way, such as films on malaria, on bird life, on breathing, on virus diseases of plants, and then of course on medical work, but many of these seem to purposely avoid the use of a microscope by using animated diagrams. Purely microcinematographic films have been made, and here I think of Comandon who even filmed micro-operations on blood-cells, and of Loveland and of Roger who studied the motility of microbes in this way. Some of these are pure research, especially those of Canti, who filmed growing body cells and cancer cells in tissue cultures, and those of Bronfenbrenner and of Bayne-Jones who studied bacterial growth, bacteriophage action and spore-germination by means of microcinematography. But the total number of microcinematographic biological films of a more advanced nature is small, both for teaching and for research. And yet living microbes or cells under a microscope are a particularly suitable subject for filming because only one person at a time can look through a microscope. The explanation of this scarcity of high power microscope films is probably to be found in one word: light. When one films the town hall, the lens of the camera concentrates all the light radiated by the town hall on a very small area of photographic film and under-exposures are rare. Filming a microbe through a microscope means that the microbe must be made to radiate light and this light is then distributed over a relatively very large area of photographic film, the area of course, depending on the magnification. It is,

therefore, necessary to shine a very strong light on the microbe to make its radiation strong enough to impress the photographic plate and the danger of "cooking" the microbe and killing it is very real. The difficulties can be circumvented in various ways and Lowndes has, for instance, already succeeded in making 1,200 microscopic pictures per second of the movement of the cilia of a protozoon. There are large opportunities waiting here for enterprising microscopists. I know that Mr. Barnard, the only man who has photographed invisible virus bodies by ultra-violet light, dislikes nothing more than to have suggestions made to him about his enterprises, but if I dared, I would certainly suggest to him to make time-lapse films of his virus bodies, which could then be seen multiplying.

I have now conducted you, via the microscope, from educational films right into pure research filming. But this need not make you think that all research films are made through a microscope, nor that all microscopic films are research, although there certainly is a wide field for research for those who can combine microscopy and filming. But the cinema camera in my opinion is definitely an instrument of research, not merely a recording instrument. That it has not been used more often as such is partly explained by Rogers' remark that biologists are inexpert technicians and technicians inept biologists.

In biology there are many movements that are too fast and too complicated to be grasped by just simple inspection, such as the flight of insects. A slow motion film in such cases allows more time for study and analysis and, moreover, the observations can be repeated any number of times on the screen. Many such films have been made that are never shown to any audience. In biology one also often deals with material that cannot be duplicated and here also making a film will allow time for leisurely study of details that might easily have passed unnoticed. Then there is the factor of the enlargement which takes place on the projecting screen and which often is helpful in the analysis of movement. Another important point for research is that, the speed of the film being known, it is easy to determine the time a certain event has taken to come off. This holds good for straight filming and for slow motion and for time lapse filming. In this way, for instance, I got to know that a whole big typhoid bacillus when attacked by its own parasites which we call bacteriophages, can be blown to smithereens in less than a sixteenth of a second, a truly dramatic happening when you see it on the screen, magnified several thousand times.

The motility of bacteria has been elucidated by the cinema camera in many instances, sometimes with quite unexpected results. Slow motion work and time-lapse observations will in time reveal biological secrets about which we have just hazy notions now.

It is to be emphasized that filming forces one to make unbiased observations. Lord Kelvin used to say that you only

understood a thing if you could make a model of it. If he had lived in our times he would have said if you could make a film of it. Setting out to make a film of a biological phenomenon one first has to eliminate all disturbing and non-essential elements, in order to get a clear view, in all senses of the word. This teaches one discipline in making observations. Also, the finished film often brings to light details, or even important factors which had originally been overlooked. It is typical of a good film that when it is screened even the maker can detect something new in it, because he gets a new " angle " by seeing his observations on the screen, and he may be driven to give novel interpretations to previous observations. A good film is not just a record of what one thought one had seen, but often brings home unexpected features. Showing a new scientific film to a critical audience of one's colleagues often is a fruitful method for the correction of one's own false first impressions of what is actually happening. Life is such a complicated affair that it must be approached from many different angles to be properly understood. As Alexis Carrel has said, living cells are continually changing, the flame of life is never steady, the contents of living cells are never still, they move and mingle, in some places they bubble like boiling water, and cinematography alone can do justice to them by bringing into the record what he calls their fourth dimension, namely, time.

Far too much teaching of biology is done on corpses and fixed material. This creates a vicious circle. The student, familiar with chiefly dead preserved and stained material, is content to go on, in his own researches, with similar material, and the need for a film camera is hardly felt. Professor Yule Bogue, himself a distinguished cinematographer, mentions that Harvard University possesses its own film unit, which can be called in by any department, but he adds that no university in Britain has anything like this, and to his regret very few scientific workers are film conscious.

There are, however, some encouraging signs that the film will get into its own for scientific work. Our Defence Force already has its own well-equipped film unit, and this equipment might pave the way for scientific developments after the war. At a meeting recently held by the National Council of Women under the guidance of Mrs. Archer, various educational authorities professed their faith in the value of the film for teaching, including the teaching of biology. Newspapers are discussing the setting up of a government commission to investigate the possibilities of film production in the Union. Let us hope this will include biological films for various purposes, including research, and microcinematography. There is a growing interest in films that are not just entertainment. What is needed above all is that more and more real scientists abandon their somewhat condescending attitude towards films. They should realise that even for work of the highest order the cinema camera provides the best possible record and means of

communicating their results. And also that the cinema camera is a new instrument of research which will open up entirely new fields. The film is not just a means of teaching elementary things to school children, it can serve much higher purposes.

But here I must, in conclusion, come back to what I said a few minutes ago. The making of films is not enough. They must also be shown, and in order to be shown, they must be copied and distributed on a large scale, and in order to be distributed they must be known. What is lacking is an international organisation for the cataloguing and distribution of the kind of films I have discussed. The present handling of scientific films reminds me too much of the position of books in the middle ages, when the libraries that had books fastened them to the table with iron chains for fear that they would disappear. Books are circulating very freely now, the same should be done with films. An international agency might disseminate complete information about films and see to it that enough copies were made to place films at the disposal of anybody at a reasonable price. As more films become available, they will stimulate further production. They need not all be photographic. Whenever I visit the bioscope I marvel at the opportunities missed when I see the cartoon. Could not a biologist with the aid of genius like Walt Disney give us an adequate film to illustrate the process of evolution? Would not the laws of heredity lend themselves admirably to the making of a similar film? To get a bit farther from home, is there no enterprising astronomer or physicist who will make a film of animated diagrams to help us visualise the movements of the heavenly bodies or the courses of electrons in the atom? Embryology would appear a most suitable subject for filming, and I know that something has been tried in this direction, but same as for the other subjects mentioned, there is a good deal more still to be done, and what has been achieved is not readily available or even known.

The international distribution of films by a central bureau would probably be easier than that of books, because films to a large extent speak an international language. All that is needed is organisation. A splendid beginning has been made in Britain by the Association of Scientific Workers, and in our own country the Film Division of the Union Education Department might suitably become our representative on an international organisation. You may object that this is hardly the time to undertake such an elaborate scheme as an international bureau. But there is no harm in planning and still less in thinking it over. My object to-day has been to stimulate interest in scientific circles in the possibilities of the cinema camera as a scientific tool, and to try and make you share my faith in the film as an instrument for the advancement of science.

South African Journal of Science, *Vol. XL, pp. 15-29*
*November, 1943.*

# RECENT ADVANCES IN NUCLEAR PHYSICS

BY

Dr. A. E. H. Bleksley,

*University of the Witwatersrand, Johannesburg.*

*Presidential Address to Section A, read 29th June, 1943.*

The study of the atomic nucleus as a separate branch of physics may be said to have begun in 1896, when Becquerel discovered the phenomenon of radioactivity in uranium. One year earlier a young New Zealand physicist, Ernest Rutherford, had entered the Cavendish Laboratory as a research student, and the history of nuclear physics for the next thirty years was to be largely dominated by the genius of this one man.

In 1902 Rutherford and Soddy proved that radioactivity is due to the disintegration of the nucleus of the atom, and for nearly twenty years this natural disintegration was the only type known to physics. In 1919 Rutherford succeeded in bringing about the transmutation of nitrogen by bombarding it with the alpha-particles of maximum energy of 7·6 million electron volts which arise in the radioactive disintegration of Radium C, but development along these lines was slow until the new wave mechanics had made it possible to provide a satisfactory theory of nuclear disintegration. In 1928 it was suggested independently by Gamow and by Gurney and Condon that on the wave theory a finite probability exists for the penetration of the potential barrier of the nucleus by a particle of energy less than that of the barrier. According to this view, a particle inside the potential well of a nucleus might escape by " tunnelling " instead of by climbing over the top, so that particles of comparatively small energy might in this way occasionally escape from a nucleus.

That the reverse might also be true was a possibility that occurred to several investigators, and in the Cavendish Laboratory Cockcroft and Walton proceeded to build a high tension generator which would enable them to bombard atomic nuclei with projectiles of comparatively low energy in order to determine whether there also exists a finite probability that such particles might enter a nucleus by penetration of a potential barrier which is certainly too high for them to climb. In April, 1932, they announced the success of these early experiments. By means of a voltage doubling circuit they were able to accelerate hydrogen nuclei by means of a potential of some 600 kilovolts, obtaining a proton beam of some 20 microamps. With this beam of energetic particles they bombarded lithium atoms,

obtaining helium nuclei of very much higher energy according to the reaction:—

$$ {}^{7}_{3}\mathrm{Li} + {}^{1}_{1}\mathrm{H} = {}^{4}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He} + 8\,\mathrm{MV} $$

This was the first of the truly artificial transmutations, and it was to start a wave of activity which has in the last ten years produced an enormous volume and variety of results. The announcement of this success was very speedily checked by Lawrence and Livingston with the first cyclotron. These investigators bombarded lithium with artificially accelerated protons of range 13 mm. in air, and observed that alpha-particles were produced with a range of 8 cms.

In the same year Chadwick discovered a new nuclear particle, the neutron, a particle of zero charge and mass approximately equal to that of the proton. Since the neutron possesses no charge, it was realised that it should enter the nucleus more readily than a charged particle would, and the possibility of nuclear disintegration by means of neutrons was demonstrated in 1932 by Feather. The possibilities were more completely investigated by Fermi and his associates, and their work culminated in the discovery in 1939 of the fission of the uranium nucleus.

That still other possibilities exist was demonstrated in the following year by Lawrence, when he succeeded in producing disintegrations by bombardment with the nucleus of the newly discovered heavy isotope of hydrogen. The deuteron, as the nucleus of deuterium has come to be called, has proved to possess several useful properties in the production of transmutations, and it is in this field that the hydrogen isotope has so far proved to have its greatest importance.

In 1934 it was discovered by Joliot-Curie that many nuclei after bombardment with accelerated projectiles undergo change to unstable forms which later disintegrate, mainly by emission of negative and positive electrons. This phenomenon of artificial radioactivity has enormously extended the table of known isotopes, several hundred such nuclear reactions now being known.

Since 1932 and the exciting period immediately following the first step by Cockcroft and Walton, the study of the details of the processes involved in the various nuclear reactions has been carried on by a very large number of investigators, both experimental and theoretical, and it is in connection with some of the more important features of this work that the present report is presented.

## Part 1—Instruments.

Throughout the period under review the development of our knowledge of the nucleus has gone hand in hand with the development of our instrumental resources. Perhaps the most

important of these instrumental problems has been that of producing particles of high energy, and so successful has the development in this direction proved, that we now have at our disposal sources of high-energy particles which surpass in energy any of the particles produced by radioactive disintegration, and which at the same time are produced in such quantities as make possible the application of the artificially radioactive substances thus available in many fields beyond physics.

The most celebrated—and perhaps the most successful—of these new instruments is the cyclotron, developed over a number of years by Lawrence and his associates until there are at present some 30 cyclotrons in operation over the world, the largest producing alpha-particles of 32 million volts energy, considerably higher than any produced in naturally radioactive sources. The intensity of the ion beams also far exceeds those from any natural source. Thus Lawrence has reported neutron beams of intensity equivalent to the neutron production of several hundred kilograms of radium-beryllium.

The greatest of the giant cyclotrons is under construction on the Berkeley Campus of the University of California. The building in which this extraordinary piece of physical apparatus is to be housed is a 24-sided steel frame, 160 feet in diameter. The magnet consists of some 3,700 tons of 2in. steel plates bolted together into a rectangular frame with one long side below ground level. Each of the 92 plates in a horizontal member is 52 feet long and 6½ feet wide and weighs 13½ tons. The pole pieces are placed in the middle of the central rectangular opening, which is 45 feet wide and 17½ feet high. Between the pole pieces there is an airgap 40 inches high and 184 inches in diameter, which will contain the accelerating chamber and electrodes. The magnetising current to each core will be carried by 12 " pancakes " of copper strip, 4in. x ½in., cooled by oil.

The high frequency equipment is on an equally large scale, occupying the space of a large two-storey house. The generators supply 2,500 kVA. at 12,000 volts, 3-phase, 60-cycle. This is rectified to 25,000 volts and so fed into the oscillator, which operates at 10 megacycles.

The equipment is designed to produce deuterons of 70 million electron volts energy at the start, and it is expected to be able to raise this value to 100 mev. Energies of about double this value will be obtainable with alpha-particles.

The principal value of the cyclotron, apart from the attainable energy, which is higher than for any other type of accelerator, lies in its capacity to produce artificially radioactive elements on a large scale, and it is in this field that its most important application has been found. It does, however, possess certain disadvantages. Thus it is difficult to provide bombarding particles of a given type with anything like a wide range in energy, and it is impossible to use the cyclotron for the acceleration of very massive or very light particles. The

electron, for example, cannot be successfully accelerated in the cyclotron, mainly owing to the considerable relativistic mass increase in an energetic electron, which in the cyclotron causes a lack of synchronism between the motion of the particle and the electric field between the electrodes.

For applications requiring very steady potentials which can be varied between wide limits, the electrostatic generator of Van de Graaff has proved to be particularly successful. The practical limit of voltage of these instruments has probably been reached, mainly on account of the difficulty of insulating successfully at potentials of some five million volts. Recent developments have, however, taken place in the use of air or an electro-negative gas such as "Freon" (dichloro-difluoromethane) under pressure as a medium for reducing the possibility of breakdown along the supporting columns, which have made it possible to build generators for several million volts in comparatively small pressure tanks. The most successful machine of this type is probably one built by Trump and Van de Graaff for high-voltage X-ray work, in which a generator for 1¼ million volts is contained in a tank only 100 inches high. The current available with this instrument exceeds one milliampere.

Very large pressure-insulated electrostatic generators have been built for several institutions in America, requiring special buildings, which add very considerably to the otherwise very reasonable cost of such a generator. The electrostatic generator differs from the cyclotron in that it is suitable for accelerating ions of any mass, and therefore forms a piece of equipment of very general applicability.

Until recently the Van de Graaff generator has provided the only available method of accelerating electrons to very high voltages, but it now seems that the induction accelerator developed by D. W. Kerst is likely to take the place of the cyclotron in this particular field. Numerous investigators have attempted to utilise, without much success, the inductive effect of a varying magnetic field in order to accelerate a circulating electron. Kerst has, however, by a very ingenious device found it possible to accelerate electrons in a preliminary design to over two million volts, while a second model has succeeded in giving electrons of some 20 million volts. With further development this device should make possible the laboratory production of electrons of sufficient energy to emulate cosmic rays. The induction accelerator has the very considerable advantage over most other methods of accelerating electrons in that it occupies relatively little space and can be built at a comparatively low cost.

Another experimental field which has proved to be of particular importance is the separation of isotopes, whereby nuclear reactions can be studied with reference to single isotopes in cases where an element occurs in nature as a mixture of several such constituents. The most celebrated of these rare

isotopes is that of hydrogen of mass 2, which has been prepared in fairly large quantities by electrolytic concentration. In this process a dilute solution of electrolyte, usually KOH, is electrolysed until it becomes too concentrated. The water is then removed, a dilute solution prepared, and the process repeated. When the original is reduced by a factor of 25,000, the concentration has increased the percentage of deuterium oxide, "heavy water," to about 99·9 per cent. One gram of "heavy water" is produced by about 30,000 ampere-hours of electricity, so that the process is both slow and expensive.

Other methods available for increasing the concentration of the rarer isotopes are distillation, chemical exchange reactions, gravity and thermal diffusion, and the use of the mass-spectrograph. Of these, the chemical separation methods appear to be the most suitable for large-scale production, although the method is slow and comparatively inefficient. Deuterium is now obtainable in large quantities, and is an established article of commerce. The cost per gram of $^{15}N$ or $^{13}C$ under laboratory conditions would appear to be around £3 or £4.

Of all the methods available, however, only the mass-spectrograph enables isotopes of any element to be separated. So far the method has not been applied to obtain anything but the minutest quantities needed—for example, in studying special nuclear reactions. New methods of producing positive ion beams would appear to offer hope that the method may become very much more efficient, and the mass-spectrograph has proved, particularly in the hands of Nier, to be a very valuable adjunct to the cyclotron.

## PART 2—EXPERIMENTAL.

The field of greatest activity in the last decade has undoubtedly been the exploration of nuclear reactions produced by various ions projected with energies ranging between some thousands of volts to over thirty millions. The number of reactions obtained is already extremely large, numbering towards a thousand, and the study of these will in due course throw light on the structure of the atomic nucleus, as well as providing a great deal of material of great value in many fields of application.

It would be impossible to attempt to describe the results of these investigations. I shall therefore merely mention briefly one of the many different cases of importance, namely, bombardment by neutrons.

It appears that slow neutrons, with energies less than 100 ev., say, tend to cause nuclear change by a process of capture followed by radioactive disintegration of the compound nucleus. Thus, for example, a very important radio-active iodine is produced by slow neutrons impinging on the iodine atom of mass-number 127, which is the only stable isotope of this element. The radio-active iodine decays with a half-life of 25 minutes to give a stable xenon isotope of mass 128, giving

off an electron in the process. The reaction may be written in the form of the equation:—

$$ {}^{127}_{53}\mathrm{I} + {}^{1}_{0}\mathrm{n} = {}^{128}_{53}\mathrm{I} = {}^{128}_{54}\mathrm{Xe} + \beta + 2\ \mathrm{MV} $$

Fast neutrons, with energies exceeding a million electron volts, cause reactions in which a fragment of the nucleus is knocked out, as in the case of the bombardment of the stable fluorine isotope of mass 19. This gives rise to a radioactive isotope of nitrogen of mass 16, together with a helium nucleus. The nitrogen decays with a half-life of 8 seconds, emitting electrons of 6 million volts energy and giving rise to the common isotope of oxygen, the reactions being summarised by the equations:—

$$ {}^{19}_{9}\mathrm{F} + {}^{1}_{0}\mathrm{n} = {}^{16}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} $$
$$ {}^{16}_{7}\mathrm{N} \downarrow {}^{16}_{8}\mathrm{O} + \beta + 6\ \mathrm{MV} $$

Reactions similar to those caused by the fast neutrons are produced by fast particles possessing charge, such as protons, deuterons and alpha-particles, and even by electrons and photons, but the charged particles do not penetrate the Coulomb field of the nucleus at low energies as in the case of the slow neutron.

A very important alternative reaction produced by both slow and fast neutrons, as well as by other particles, arises in the case of the nuclei of uranium and thorium, in which the atom is very literally split by the bombarding particle, giving rise to two fragments of comparable size.

This reaction, totally different from any other previously observed, was finally identified by Hahn and Strassman in 1939, a discovery which may well in future years lead the historian to attach to this date an importance greater than would attach to it on account of the outbreak of the Second World War. Hahn and Strassman found that when uranium is bombarded with neutrons, certain atoms chemically analogous to radium which had previously been detected were actually due to barium, while at the same time other elements which appeared chemically to be isotopes of manganese, ruthenium, etc., also were formed. In addition, a set of elements of slightly lower atomic weight were discovered, and it became clear that an entirely new type of nuclear reaction was taking place under the given conditions.

Subsequent work has shown without doubt that the phenomenon is actually due to a fission of the unstable uranium isotope formed by neutron capture. This very massive nucleus is unstable with a new kind of instability, and breaks up into two portions with masses in the approximate ratio of 3 to 2.

These fission fragments are released with very considerable energy and are themselves unstable, decaying by electron or neutron emission until a stable end-product is reached.

Subsequent work has shown that thorium atoms also undergo fission in a similar way, and that the bombarding particle may be a neutron, proton, deuteron, alpha or photon. The reaction is most probable in the case of so-called thermal neutrons of very low energy in the case of uranium, and of fast neutrons in the case of thorium.

In the case of uranium, it was shown by Nier, Booth, Dunning and Grosse that the thermal neutron reaction was due to the rare isotope of mass 235. In order to prove this, they separated the three normally occurring isotopes of masses 234, 235 and 238 by means of a mass-spectrograph built by Nier. Bombardment of these separated fractions showed quite clearly that the isotope responsible for slow-neutron fission was that of mass 235, while fission by fast neutrons occurs in the case of U 238.

The process has been pictured by Bohr as follows: A neutron enters a heavy nucleus and is temporarily captured, forming an excited compound nucleus which is unstable and can break up either by ejecting a neutron or by undergoing fission into two fragments of more nearly equal mass. The relative probabilities of these processes vary with the energy of the incident neutron. In particular, if the neutron is of high energy, we may have 239 U$>$238U + n, but find the 238U so excited after losing the neutron that it can still undergo fission. In this case, the higher the state of excitation of the resulting nucleus the greater the probability of fission, so that we may expect fission to become more probable in this case, with increasing energy of the incident particle. This is found to be the case for fast neutrons and for the charged particles which also produce fission. Thus Fermi and Segré found typical fission fragments when ammonium uranate is bombarded with 32 mev. alpha particles, but that lower energies appear to give no such reaction.

In the case of the thermal neutron reaction with 235 U it would appear that an unstable isotope of mass 236 is formed, which immediately undergoes fission. This would explain why this isotope is not found in nature.

The fragments formed in the fission process have in general too many neutrons for stability, and therefore undergo disintegrations until a stable atom arises, either by emitting the excess neutrons or by changing neutrons to protons by emitting electrons or by both of these processes. Observations have shown that during fission neutrons are produced, probably simultaneously with the fission. Zinn and Szilard, for example, found on an average 2·3 neutrons per fission. In the case of the fission of 235 U, this neutron emission is of great importance in connection with the possibility of chain reactions.

In this case it is clear that if a neutron of low energy causes fission of a nucleus of U in a mass of the material, further neutrons will be produced, which will be slowed down by elastic collisions until they in turn are absorbed by further nuclei, thus giving rise to more fission reactions and to more neutrons and so on. If the mass of uranium is sufficiently extended, so that the neutrons so formed do not escape from the mass before being absorbed, the possibility exists of a chain reaction which will increase at an enormous rate.

Since it is found that at each fission an amount of energy approaching two hundred million electron volts is evolved, it is clear that such a chain reaction might well prove catastrophic to the investigator. Apart, however, from this possibility, it would appear that this reaction might well be used to obtain power from nuclear sources, in which case the long-awaited era of "atomic power" might well be at hand. The problem of the control of the explosive possibilities of masses of uranium is one that would require solution before an attempt could be made to harness the enormous reserves of energy available in the nuclei of uranium and thorium, but it is most unlikely that the recent cessation of activity, as indicated by the absence of papers on fission in the scientific journals of the last year or so, is in fact taking place. The possibility of atomic power is of sufficient military importance to render it extremely unlikely that any important results will now be published until after the war.

An indication of the possible energy available is provided by an estimate by Flügge to the effect that one cubic metre of uranium oxide might develop one million million kilowatt-hours in one-hundredth of a second. Stated in this way, the military potentialities of the situation become obvious. In the long run, however, it is in the gradual release of this energy that the method will be of value. In a general discussion of this topic, Roberts and Kuper have shown that under present conditions the cost of raw material—namely, uranium—would be about one-eighth of that of coal to produce the same total energy.

An interesting by-product of the investigations of fission in uranium has been the discovery of elements beyond atomic number 92. When uranium is bombarded with neutrons, not all the compound nuclei so formed undergo fission. An alternative reaction arises whereby the $^{239}U$ so formed undergoes radio-active decay with the emission of an electron, the half-life for this transition being 23 minutes. The end-product of this reaction is an element of mass number 239 and atomic number 93, thus one of the long-sought-for transuranic elements. Nishina and his associates have also announced a further radio-activity in uranium bombarded with fast neutrons, the half-life being 6·5 days and electrons being emitted. This, they suggest, is due to the decay of 237 U formed from 238 U in a reaction in which the bombarding neutron sets free two neutrons from

the nucleus. The resultant product would have mass number 237, atomic charge 93, and would be an isotope of eka-rhenium.

In addition to an extension of the periodic system in this direction, the building of isotopes which do not often occur naturally has led to the completion of the table of elements by the synthesis of the remaining four elements, which at the time of discovery of artificial radioactivity were numbers 43 (eka-manganese), 61 (rare earth), 85 (eka-iodine), 87 (eka-caesium).

Of these, element 87 was discovered by Perey as a rare branching product in the actinium family of naturally radioactive elements. Perrier and Segré found 43 in products of neutron bombardment of molybdenum. Element 61 has probably been obtained by deuteron bombardment of neodymium, but owing to chemical difficulties in separating the rare earths, it has so far not been studied. Element 85 has been prepared by bombarding bismuth with alpha-particles.

## PART 3—THEORY.

The enormous activity in experimental work has been accompanied by a flood of theoretical investigations of comparable dimensions. It is to be feared, however, that comparatively little of this latter work is likely to maintain its importance for any length of time. It appears that the general principles of wave mechanics apply in the domain of the nucleus, as in the extra-nuclear phenomena of the atom, but the application of the theory to details has not always met with any particular success.

So far a good deal of the most successful theory has been of a qualitative nature, as in the case of the Bohr theory of fission. According to this view, the nucleus behaves somewhat like a drop of liquid, which when set into vibration may divide into two drops. This " liquid drop " model has met with some success. A further liquid analogy which has proved useful is that of the "evaporation" of nuclear particles from heavy nuclei. In this case, too, the treatment has been largely by analogy, and the details of the mathematical treatment have not been worked out. They provide, in a sense, classical rather than strictly quantum-mechanical treatment of the relevant phenomena, a treatment which is largely to be justified by the comparatively large number of elementary particles occurring in a massive nucleus.

Among other fairly successful applications of theory might be mentioned the theories of $\beta$-decay. The early form of the theory, due to Fermi, proved not always to fit the observations, and a modification was proposed by Konopinski and Uhlenbeck. Of the two, the Fermi theory appears to satisfy the observations better in the region of high energy, the Konopinski-Uhlenbeck theory on the other hand fitting more closely in the regions of lower energy. It is symptomatic of the present state of theory

that, according to Walke (Walke, 1939), "it is tempting to employ a linear combination of the two distributions to represent the whole range of results." It need hardly be mentioned that an empiricism of this type is scarcely to be called theoretical physics.

Some striking successes have, however, been obtained, of which one may mention the prediction of the neutrino by Fermi and that of the meson by Yukawa. The former elementary particle, which probably possesses no mass and does not interact appreciably with matter, will by definition prove extremely difficult to detect. Experimental evidence for its existence is, however, slowly building up.

The story of the meson will serve to illustrate the present-day tendency in nuclear theory. The existence of a particle of mass intermediate to those of the electron and the proton was first assumed by Yukawa in order to explain the existence within the nucleus of forces of attraction between the nuclear constituents, neutrons and protons, this force being in addition to the ordinary Coulomb repulsion between the like charges on the protons.

The Coulomb law is a direct result of the wave equation

$$\triangle^2\phi - \frac{1}{c^2} \cdot \frac{\delta^2\phi}{\delta t^2} = o$$

which for a steady field reduces to

$$\triangle^2\phi = o$$

The spherically symmetrical solution of this for a point-charge at the origin is

$$\phi = \frac{\text{constant}}{r}$$

which gives rise to an inverse-square force.

If we wish to add to this force an additional term which will be preponderant for small distances, and negligible in comparison with the Coulomb force when the distance is large, it is necessary to change the wave equation. Assuming the wave equation to be linear and of second order and invariant to a Lorentz transformation, Yukawa was led to the only possible generalisation of the above equation, namely:—

$$\triangle^2\phi - k^2\phi - \frac{1}{c^2} \cdot \frac{\delta^2\phi}{\delta t^2} = o$$

where $k$ is a constant. For a steady field this reduces to

$$\triangle^2\phi - k^2\phi = o$$

which has a spherically symmetrical solution

$$\phi = \text{constant} \times \frac{e^{-kr}}{r}$$

which is of the required character. The wave equation so found is the relativistic wave-equation of a particle of mass $hk/2\pi c$,

which is of an order intermediate to that of the electron and the proton when $k$ is assumed to have a reasonable value determined by the known range of the neutron-proton forces.

This theory was introduced in 1935. During the next year an investigation of the tracks of cosmic rays in cloud chambers led several investigators to the conclusion that the penetrating component in cosmic rays must be a particle of electron charge and of mass some 150 times that of the electron. This particle was immediately identified with Yukawa's hypothetical particle and a number of rival designations proposed. The tendency at present is to use the term mesotron or meson, of which the latter is probably preferable.

Yukawa's theory had thus correctly predicted the existence of the meson. When, however, we come to compare the further results of the theory with observation, we find that the detailed requirements of observation are in no way satisfied, and it becomes necessary to make further postulates. Thus Bethe has given a meson-theory in which at least three forms of meson are required, negatively charged, positively charged, and neutral. More recently, Marshak has shown that the neutral meson is not indispensable to the theory of nuclear forces. Peierls has suggested that further difficulties in the theory may be met by postulating that there are mesons of zero spin and mesons of unit spin, and arranging the available parameters in a special way in order to ensure convergence of the solution to the equations thus derived. Again it becomes obvious that there is a strong empirical element in the theory.

If one may be permitted a word of criticism, it seems that at present the tendency is to produce a theory at all costs. It would be well to remember that the course of theory in the past has generally lagged well behind that of observations. There comes in the history of a science a stage during which the observational data are collected. Then follows a period during which the data are worked into empirical relations, and only thereafter does it generally become possible to weld the whole into a single coherent theory.

Thus, before it was possible for Kepler to derive his three Laws of Planetary Motion, it required the labours of a Tycho Brahe to produce the mass of observational evidence from which these three empirical generalisations might be drawn. But without the Laws of Kepler it would have been impossible for Newton to arrive at his Law of Universal Gravitation, the generalisation which made it possible ultimately to bind all observed phenomena of planetary motions into a coherent whole.

It would appear that the present stage in nuclear physics is rather that of Kepler. It would seem that we need to work for a while in a purely empirical fashion, until from the mass of observational material that has accumulated in the last decade it becomes possible to sort the essentials into empirical

generalisations. Then, and only then, will it become possible to attempt to found with success a comprehensive theory to enter on the Newtonian phase of the science.

## PART 4—APPLICATIONS.

Important as the development of nuclear physics has been to the physicist, it is perhaps true that its importance is even greater outside the fields of physics. Already the scope of the applications of our knowledge of nuclear reactions has become extremely large, and it is entirely impossible to report progress except in one or two special examples.

In astronomy the outstanding problem in connection with the theory of stellar structure is that of the generation of stellar energy. It has long been known that the light and heat radiated by a star must come ultimately from some sub-nuclear source, since it is only in the atom that the enormous amounts of energy radiated during its lifetime by a star can be stored. Details of the actual processes whereby the conversion from matter to radiation may take place have until recently been entirely lacking. With our present knowledge of the energetics of nuclear reactions, however, it becomes possible to estimate the contributions to stellar energy generation due to various nuclear reactions.

The most complete discussion of the possibilities in this connection are due to Bethe, who proposes as the main source of energy in the average star a cycle of reactions involving the lighter elements, which can be represented by the set of equations:—

$$\begin{array}{lcccccc} {}^{12}C & + & {}^{1}H & = & {}^{13}N & + & \gamma \\ {}^{13}N & & & = & {}^{13}C & + & \beta+ \\ {}^{13}C & + & {}^{1}H & = & {}^{14}N & + & \gamma \\ {}^{14}N & + & {}^{1}H & = & {}^{15}O & + & \gamma \\ {}^{15}O & & & = & {}^{15}N & + & \beta+ \\ {}^{15}N & + & {}^{1}H & = & {}^{12}C & + & {}^{4}He \end{array}$$

The effect of the cycle is therefore to construct helium atoms from protons, the carbon nucleus serving in the vast majority of reactions simply as a catalyst. It is computed that in about one case in a hundred thousand the last reaction leads to the stable ${}^{16}O$ instead, so that in this case the carbon nucleus is permanently lost.

The details of this theory do not as yet provide a complete solution to the problem, but it does enable an estimate of the radiation of a main-sequence star to be given which is at least of the correct order of magnitude.

In biology the major field of application has consisted in the study of the metabolism of various elements by means of labelled atoms—atoms, in fact, of the unstable radioactive isotopes of the elements concerned, produced for the great part by means of bombardment with the high energy particles produced by the cyclotron.

The idea here is particularly simple. Suppose the biologist to be interested in, for example, the metabolism of iodine in the animal body. Previously the only available method lay in the painstaking analysis of the tissues of the animal after ingestion of iodine, a method which is obviously destructive. Since, however, there are known to exist isotopes of the normal atom, chemically and hence physiologically indistinguishable from it, and possessing the property that in a reasonably short time they disintegrate, giving rise to energetic electrons which can very readily be detected by physical means wherever they arise in the body, these atoms can be used to trace the iodine in the course of its wanderings in the body, thus providing the required information.

Since, too, the detection of radio-active iodine by physical methods is probably some millions of times more sensitive than the chemical methods which are available for the same purpose, it follows that the normal tolerance of the body to the chemical need not be exceeded.

This method of using labelled atoms—" tracer " atoms as they are commonly called—has been applied to study the metabolism of more than twenty biologically important elements, such as phosphorus, iron, iodine, calcium, sodium, potassium, nitrogen, and certain fundamental organic compounds, such as vitamin $B_1$. This latter has been traced by synthesising vitamin $B_1$ so that it contains radioactive sulphur, and then following the trail of these labelled sulphur atoms. Very ingenious chemical methods have been devised to bring about the synthesis of suitable organic compounds from carbon dioxide containing radio-carbon, $^{11}C_6$, which has the very short half-life of 21 minutes. The time available for synthesis is therefore at most an hour or an hour and a half if the radioactivity is not to be too much reduced before the material can be applied biologically. Alternatives to chemical methods of synthesis have been provided in some cases by the use of specific micro-organisms. Thus methane bacteria have been used to give appreciable quantities of methane containing the radio-carbon in 40 minutes. The scope for investigation here seems to be almost unlimited, and it would seem that there is here a fruitful field for collaboration between physicist and micro-biologist.

In medicine the radioactive isotopes of certain elements would also appear to have considerable importance. Thus it is possible to treat thyroid tumours by bombardment with the energetic $\beta$-rays released by radio-iodine from within the organ itself, the effects of such radiation being very largely confined to the organ.

Promising results have also been obtained in cases of human leukaemia by making use of the fact that phosphorus is strongly concentrated in the bone-marrow. Hence if radio-phosphorus is administered, it tends to collect in the bone-marrow, where it then proceeds to disintegrate, giving rise to highly energetic

decay-products which thus provide irradiation of the bone-marrow *from the inside. The method is very much simpler to apply than the standard treatment by whole-body radiation with* X-rays.

As an alternative to radium or deep X-ray therapy, the use of neutrons promises also to become of importance. It is known that fast neutrons have profound biological effects, although a great deal of work remains to be done in determining the precise effect of these radiations.

Slow neutrons have also been studied for their possible therapeutic value. Another possible application here lies in the fact that boron and lithium nuclei capture slow neutrons and emit energetic alpha-particles. If the boron or lithium atoms can be localised in the tissues where the radiation is desired, the alpha-rays can be released in these tissues, and therefore provide the radiation without damage to tissues lying nearer the surface or in the vicinity. Since the absorption of slow neutrons by boron or lithium is very much more pronounced than by other atoms occurring in the body, radiation effects would be entirely localised. Various attempts have been made to localise these elements in tumours, with preliminary success, but again the work requires more investigators.

## Conclusion.

This report covers only a very small portion of the important developments in a very rapidly growing body of knowledge. It is hoped, however, that it will help to focus the attention of workers outside of physics in the vast fields of investigation which are being opened up by the use of the new instruments and techniques. The possibilities have so far hardly been explored, and we may look forward to a long period of intense activity in many branches of science resulting from the work of the last ten years.

## BIBLIOGRAPHY.

NOTE.—I have included in this list of papers those references which will be of value to investigators not familiar with the literature, who should wish to orient themselves in one of the topics discussed in the foregoing.

### Part 1.

(a) *The cyclotron.*

LAWRENCE, E. O. and COOKSEY, D.: "On the apparatus for the multiple acceleration of light ions to high speeds." *Phys.Rev.*, **50**: 1131-1140 (1936).

KRUGER, P. G. and GREEN, G. K.: "The construction and operation of a cyclotron to produce one million volt deuterons." *Phys.Rev.*, **51**: 699-705 (1937).

HENDERSON, M. C. and WHITE, M. G.: "The design and operation of a large cyclotron." *Rev.Sci.Inst.*, **9**: 19-30 (1938).

MANN, W. B. "The cyclotron and some of its applications." *Reports on Progress in Physics*, **6**: 125-136 (1940).

KURIE, F. N. D.: "Present-day design and technique of the cyclotron." *Journ.App.Phys.*, **9**: 691-701 (1938).

(b) *Electrostatic Generator.*

VAN DE GRAAFF, R. J., COMPTON, K. T. and VAN ATTA, L. C.: "The electrostatic production of high voltage for nuclear investigations." *Phys.Rev.*, **43**: 149-157 (1933).

TRUMP, J. G. and VAN DE GRAAFF, R. J.: "A compact pressure-insulated electrostatic X-ray generator." *Phys.Rev.*, **55**: 1160-1165 (1939).

TUVE, M. A., HAFSTAD, L. R. and DAHL, O.: "High voltage technique for nuclear physics studies." *Phys.Rev.*, **48**: 315-337 (1935).

HERB, R. G., PARKINSON, D. B. and KERST, D. W.: "The development and performance of an electrostatic generator operating under high air pressure." *Phys.Rev.*, **51**: 75-83 (1937).

PARKINSON, D. B., HERB, R. G., BERNET, E. J. and MCKIBBEN, J. L.: "Electrostatic generator operating under high air-pressure." *Phys.Rev.*, **53**: 642-650 (1938).

HERB, R. G., TURNER, C. M., HUDSON, C. M. and WARREN, R. E.: "Electrostatic generator with concentric electrodes." *Phys. Rev.*, **58**: 579-580 (1940).

WELLS, W. H.: "Production of high energy particles. *Journ.App. Phys.*, **9**: 677-689 (1938).

WELLS, W. H., HAXBY, R. O., STEPHENS, W. E. and SHOUPP, W. E.: "Design and preliminary performance tests of the Westinghouse electrostatic generator." *Phys.Rev.*, **58**: 162-173 (1940).

(c) *Induction accelerator.*

KERST, D. W.: "The electron induction accelerator." *Phys. Rev.*, **60**: 47-52 (1941); **61**: 93 (1942).

PART 2.

WALKE, H. J.: "Induced radio-activity." *Reports on Progress in Physics*," **6**: 16-47 (1939).

TURNER, L. A.: "Nuclear Fission." *Rev.Mod.Phys.*, **12**: 1-27 (1940).

LIVINGSTON, M. and BETHE, H. A.: "Nuclear Dynamics, Experimental." *Rev.Mod.Phys.*, **9**: 245 (1937).

UREY, H. C.: "Separation of Isotopes." *Report on Progress in Physics*, **6**: 48-77 (1939).

PART 3.

BOHR, N. and WHEELER, J. A.: "The Mechanism of nuclear fission." *Phys.Rev.*, **56**: 426-450 (1940).

BOHR, N.: "Successive transformations in nuclear fission." *Phys.Rev.*, **58**: 864-867 (1940).

TURNER, L. A.: "The missing heavy Nuclei." *Phys.Rev.*, **57**: 950-957 (1940).

PART 4.

(a) *Stellar energy generation.*

BETHE, H. A.: "Energy production in stars." *Phys.Rev.*, **55**: 434-456 (1939).

BETHE, H. A. and MARSHAK, R. E.: "The physics of stellar interiors and stellar evolution." *Reports on Progress in Physics*, **6**: 1-15 (1939).

(b) *Biological applications.*

EVANS, R. D.: "Applied Nuclear Physics." *Journ.App.Phys.*, **12**: 260-269 (1941).

HAMILTON, J. G.: "The application of radio-active tracers to Biology and Medicine." *Journ.App.Phys.*, **12**: 440-460 (1940).

South African Journal of Science, *Vol. XL, pp. 30-36*
*November, 1943.*

# CHEMICAL ENGINEERING IN SOUTH AFRICA.

BY

Bernard Segal, D.Sc.(Eng.), M.I.Chem.E.

*Presidential Address to Section B, read 29th June, 1943.*

I wish to thank you for the honour in having elected me President of Section B.

In his address last night, our President remarked that a presidential address should err on the side of popularity rather than be a cold-blooded exposition of scientific facts. I am afraid that I cannot follow that injunction with the subject which I have chosen. I shall have to lead you into a very material field —one which at times is far removed from cultural considerations.

The primary purpose for my choosing the subject " Chemical Engineering in South Africa " is to make you aware of the existence of the profession and of the part which it plays in industry. I hope that, by stimulating interest, we may eventually benefit to the extent that adequate facilities for training in South Africa in this professional course will be established.

In any national stocktaking the degree of industrialisation occupies an important place in the balance sheet. The function of industry is to provide for present needs as well as to safeguard against shortages. In this respect, chemical industry occupies an important place in national progress, and contributes substantially towards national welfare. The ramifications of applied chemistry are deeply interwoven with the fabric of modern civilisation. By its very nature, industrial chemistry caters for the present, points the way towards preparing for the future and, what is more, from an economic standpoint, blunts the power of monopolisation of essential products.

We are well aware of the industrial progress which our country has made in the past decade, and we are witnessing the results of the impetus given to industrial self-sufficiency by the present world war. No less than other industries, chemical industry has made strides which raises it to one of the more important contributors to our national income. The annual contribution of the chemical industry, based on 1938-39 figures, is over 12 million pounds, and this is seven per cent. of the gross value of the output of all branches of our national industries. This figure represents the amount directly contributed by the chemical industries and does not include industries where chemical technology occupies an important place; it is only

exceeded by the food, drink and tobacco industries (27 per cent.), engineering (18 per cent.), building and contracting (nine per cent.).

Our chemical industry is very highly developed in certain lines; in others, it has maintained a level commensurate with limited scope, limited enterprise and limiting economic factors. The keen interest which is now being shown in chemical industry must be developed to the fullest extent so that what is being built up now can remain a permanent asset to our economic structure. Fortunately our industries are still young and amenable to wise counsel, and now is the time to put them on a scientific basis.

Industrial chemistry has been defined as the " chemistry of dollars and cents " and as such it enters the realms of industrial or commercial enterprise. The elements of a successful industrial enterprise are equipment and personnel; when these two are co-ordinated properly we have a successful business. Successful industrial operation in the true economic sense means low cost of production. This, therefore, is the function of industrial chemistry; the proper co-ordination of scientific principles by trained personnel, on a scale where correctly designed plant and equipment serve the accomplishment of chemical processes with the object of producing commodities at a cost which must be both economic and competitive in the sphere of business.

Like every science, industrial chemistry has progressed with the increase of knowledge, and empirical methods are rapidly being discarded and replaced by proven scientific practice. Science has taught what to do and to-day few indeed can afford the risk of going into a business without the knowledge of knowing what to do. In the sphere of chemical industry the burden of this knowledge is vested in the chemist and chemical engineer. It is almost fifty years since practical thought was given to the recognition of the necessity of training men who, besides being proficient in chemistry and its application to industrial problems, would possess knowledge and experience in the principles of engineering. The Institution of Chemical Engineers has adopted the following definition: " A chemical engineer is a professional man experienced in the design, construction and operation of plant and works in which matter undergoes a change of state and composition."

Chemical engineering is not a pot-pourri of chemistry and various branches of engineering. It is itself a branch of engineering, the basis of which is to control the sequence of chemical processes and to conduct them on an industrial scale. Chemical engineering co-ordinates unit operations quantitatively and provides the equipment whereby they can be carried out. It differs from chemistry and from industrial chemistry in that these two are concerned primarily with the chemical reactions involved in the operations. Chemical engineering is responsible for efficient

operation, for the elimination of uneconomic production and thus for making a profit.

In an article on "Chemical Engineering in South Africa" (Walker and Segal, "Industrial Chemist," June, 1936), the authors make the following statement: "The industrial development of the Union has naturally called into service trained technical men, and, particularly in the chemical industries have the functions of the chemical engineer been fully appreciated. Further expansion must ultimately call into being engineering shops for the manufacture of chemical plant, when the fuller functions of the chemical engineer will be in demand."

In analysing this subtle process of appreciation we must confess that in the Union the value of plant and equipment was held in greater esteem than the chemical engineer. In other words, it has always been recognised that plant is more indispensable to chemical industry than the chemical engineer. Two factors acted against attributing the same degree of indispensibility to the chemical engineer; one, the risks of investing in the chemical engineer the onus of designing a plant, and two, the inability of the established engineering works to manufacture chemical plant.

We must bear in mind that South Africa like every other country standing on the threshold of industrial expansion, has always looked to the old established European and American countries for guidance. The result has been that the risk of a greater capital outlay was held to be a better investment than the risk of supposed improvisation. We cannot deny that there has always been a desire for plant engineers to manufacture at least some of their own plant units locally, but here the stumbling block has been that the engineering industry had not developed the manufacturing side sufficiently. Our engineering industry is, as yet, more of the nature of a "servicing and maintenance industry," and until it is adequately catered for by the metallurgical and other allied industries we cannot count on its entering the manufacturing field. That our engineering industry can reach a versatility of accomplishment has been amply proved by its reaction to the strenuous demands of the present war.

This aspect of the problem must, therefore, await its solution in the results of the correlated efforts of all the engineering industries. It recalls again the interdependence of the sciences. It demands the optimum development of our resources of capital, of technical skill and of labour.

The problem of personnel—that is, the training of scientific men for the manifold demands of chemical industry—is one which is of paramount interest to this Association for the advancement of science.

Whatever the later application may be, the fundamental requirements for any chemical training must be, in my opinion, a sound knowledge of theoretical and practical chemistry. It is

only when this basic knowledge is obtained that we can afford to consider various branches of specialisation. Which is more important to the chemist, the knowledge of chemical facts or the memorisation of academic theories? After all, the heavy chemical industry in England was built up on the knowledge of oxides of sulphur, of the oxides of nitrogen and of the properties of the alkalies. It must not be inferred that I consider academic theories of no importance, but they must take their correct place in the sequence. Mark Twain said that part of the secret of success in life was to eat what you like and to let the food fight it out inside. I doubt whether this would hold for the quasi-training in chemistry which is so often given by some of our institutions. "The trouble with present-day education is that it covers the ground without cultivating anything in it," says Ferris. It is the function of the educational institutions to carry out the proper cultivation and to enhance the fertility of the mind. In technical science, particularly one in which so much work is being done and one which has made such tremendous strides in recent years, the soundness of the fundamental training is the corner-stone of the industrial superstructure.

Reverting to chemical engineering, we must consider the subject of training in the light of what is expected of the qualified chemical engineer. We must acknowledge that chemical engineering is dedicated wholly to the profitable production of a variety of useful commodities. Thus we arrive at a differentiation between methods of systematic training. Since higher education is vested in Universities, we must recognise that training should serve a two-fold purpose; to develop the general education and cultural status and to prepare a student for the material purpose of serving in a profession. All this must, of course, be done in a reasonable number of years. The cultural aspect must also be fostered so that gross materialism does not smother the finer qualities of the mind.

Continental and American practice is in favour of a combination of an undergraduate course in science, with chemistry and mathematics as majors, with a post-graduate course in chemical engineering. In South Africa, particularly at the Institution with which I was connected for a number of years, the University of the Witwatersrand, the course in chemical engineering is an undergraduate course. A bold comparison can hardly be made between our practice and that overseas; we must bear in mind the conditions set by and the requirements demanded by an industrially adolescent country, such as South Africa, and by countries where chemical engineering is an old established industry. In assessing the value of an educational and training course in chemical engineering, we must take into account a series of complex circumstances automatically set by the industrial needs of the country. Crystallisation of the ideas as to what should constitute an adequate course has proved that those qualified must be familiar with both chemistry and

engineering and that a sound knowledge of the scientific foundations of different subjects is of greater importance than an elaborate knowledge of detail.

The limitations of an undergraduate course may be criticised on the grounds that they would turn out professional men to a standard pattern. I doubt if this is of great disadvantage to our country. Rarely can a student predict what the nature of his future work will be and, therefore, what he must be given is a sound fundamental training so as to make him as adaptable as possible. In a course of this kind undue specialisation is avoided. I believe, therefore, that in so far as South African conditions are concerned a four-year undergraduate course in chemical engineering is desirable.

The standing of chemical engineering as a profession was first officially recognised in the United States of America by the establishment of the Institution of Chemical Engineers in 1908. In Britain, the Institution of Chemical Engineers was founded in 1921-3; its establishment was directly attributed to the Great War, the Director-General of Explosives Supplies, the late Lord Moulton, drawing attention to the urgent necessity for the training of chemical engineers. The American and British Institutions are affiliated bodies. During the past 25 years chemical engineering has been universally recognised as a profession and many Universities and Technical Institutions have established chairs of chemical engineering. In South Africa the first Department of Chemical Engineering was founded in 1913 as the Department of Chemical Technology in the Faculty of Engineering of the S.A. School of Mines and Technology, which later became the University of the Witwatersrand. Up to the end of 1942, 109 students have graduated with the degree of B.Sc. in engineering in the branch of chemical engineering. From an analysis taken prior to the present war, I found that 92 per cent. of the graduates followed the profession and many of these have attained a high professional status.

As pointed out previously, the chemical engineering course in England and in America is preferably taken as a post-graduate course to the B.Sc. degree; the course is an intensified one, over a period of two years, embodying the scheme of training laid down by the Institution of Chemical Engineers and leading to the award of an M.Sc. degree. In South Africa the course is taken as an ordinary degree course and it has been adjusted to follow the scheme of the Institution.

It is very difficult to suggest a course of training for an undergraduate course, particularly where any specialisation is to be avoided. Chemical engineering covers a very wide field and it should be necessary only to give the student a sound knowledge of the fundamentals of the various subjects and to encourage his initiative in full measure.

In a four-year course, I would suggest that the course of study to suit our conditions takes the following form:—

FIRST YEAR.—1, Mathematics; 2, Applied Mathematics; 3, Physics; 4, Chemistry; 5, Geology and Mineralogy.

SECOND YEAR.—1, Mathematics; 2, Chemistry (Organic, Inorganic, Physical); 3, Engineering Drawing; 4, Strength of Materials; 5, Fluid Mechanics; 6, Electrical Technology.

THIRD YEAR.—1, Chemistry (Organic, Inorganic, Physical, Industrial Stoichiometry); 2, Chemical Thermodynamics; 3, Thermodynamics of Heat Engines; 4, Fuels and Combustion; 5, Metallurgy; Metallography; 6, Economics.

FOURTH YEAR.—1, Unit Chemical Engineering Operations; 2, Materials of Construction; 3, Chemical Engineering Design and Construction; 4, Layout, Organisation and Management of a Factory; 5, Chemical Engineering Economics.

It is not necessary to formulate with precision any course. The actual details and scope of the instruction will depend on conditions and demands made by industry or even by the interest devoted by an institution to special subjects.

Added to instruction in theory must be sound instruction in laboratory work. Those who have had experience in laboratory work will admit that the interpretation of the results is of great importance, and therefore training in the writing of reports deserves special attention.

Vacation work should form an integral part of the course, since it is only under these conditions that a student realises the meaning of the industrial application of chemical processes. This method of training is particularly important in South Africa where as yet laboratory equipment and facilities are too limited. In an analogous way, students derive very useful instruction from visits to factories and excursions of this nature should be as varied as time and opportunity permit.

In formulating a course of this type, which does not differ in great detail from the one at present given, I bear in mind the peculiar conditions set by our country. Chemical industry is at present in a state of flux and what is required of a newly-graduated student is that he finds his feet quickly in any factory for which he has not had specialised training. Thus a greater versatility is demanded of him. On the other hand, the initial scope of a new undertaking is usually limited, so that a graduate with only a small measure of practical experience is not overwhelmed. A newly qualified student in chemical engineering can hardly be called a chemical engineer since he still lacks the experience which only practice and maturity can bring. As " the end of courtship is the beginning of marriage," so the end of the initial scholastic period is the beginning of a long period of practical training in the location, layout, design, finance, operation and management of chemical plant.

An historical survey of chemical engineering in South Africa must take cognisance of the struggle of the " pioneer " South African graduates. It was a struggle of the trained professional man against entrenched men of practice. I am very glad to say that the profession is now fully recognised and chemical

engineers need no longer be engineers amongst chemists and chemists amongst engineers.

The way for our future chemical engineers has been paved, and provided capable and efficiently trained men are produced there need be no fear for the future of the profession.

What is still lacking to a certain degree is the opportunity for research and investigation. There must be a greater public spiritedness among industrialists; they will find that the process is cyclic and that they will benefit from the fruits of the researches which they can help to initiate.

To foster this spirit is one of the main objects of this Association, namely, to give " a stronger impulse and a more systematic direction to scientific enquiry and research."

It was Francis Bacon who said: " The division of the sciences are like the branches of a tree that join in one trunk." With the progress of scientific method, with the application of science to all fields of human activity, with the devotion of workers to the principles of science, this definition gains its full significance. No branch of science stands in an isolated position.

Science cannot as yet explain the life impulse but it can help to ameliorate the conditions of living. And this is precisely the purpose of industrial chemistry—to make easily available to all, that which would otherwise be beyond the reach of many.

In the present clouded days, the many blessings of industrial progress are overshadowed by the ravages of modern warfare. We are aware of a sinister misapplication of science, or what has been frequently referred to as the " frustration of science." The cure lies in the correct direction of scientific thought; it calls for active citizenship by scientific men who must not be trammelled only with professional work; it demands from this Association " to strive, to seek, to find and not to yield."

South African Journal of Science, *Vol. XL, pp. 37-56, November, 1943.*

# TOWARDS A NATIONAL PASTORAL POLICY.

BY

D. Meredith,

*African Explosives and Industries, Ltd.*

*Presidential Address to Section C, read 28th June, 1943.*

## Introduction.

During the past ten years there has been an increasing realisation of the fact that the Union is not primarily a grain-producing country with large tracts of fertile soil only waiting to be exploited and that no very considerable expansion in the production of citrus or deciduous fruits can be expected as the areas in which it is possible to grow these crops on a commercial scale are strictly limited. Indeed it is now accepted by most agricultural authorities from our great leader Field-Marshal Smuts downwards, that South Africa is a pastoral country and that, as a consequence, agricultural policy should be based largely on the development and better utilisation of pastoral resources. The Union possesses extensive areas of natural grazing or veld, rich in valuable grass species and, notwithstanding the tendency of many people to stress the frequent occurrence of droughts, enjoys a fairly reliable rainfall of 20 inches per annum or more over the eastern half of the country. This address is concerned almost entirely with the possibility of realising the potentialities of these extensive grasslands.

## The Veld.

The areas of veld or natural grazing in the Union of South Africa, disregarding provincial boundaries and excluding native reserves, may be divided into the following four categories:—

1. Arid area, receiving less than 10 inches rainfall per annum. This area, including most of the Karroo and the North-western Cape Province, amounts to 29 million morgen and. according to the 1936-37 agricultural census, supports a total of 1,037,000 livestock units. In this paper, a method used by Clarke has been followed whereby numbers of livestock are calculated as mature livestock units. In making these calculations, allowance was first made for the age groups of the different classes of livestock and then all animals were converted into livestock units by taking horses and mules as ·75, donkeys as ·5 and sheep and goats as ·143 of a livestock unit.

The figures given in the 1936-37 census report have been used in preference to those of later reports, as there the age-

groups of the classes of livestock are given, whereas in subsequent years only totals are given.

2. Semi-arid area, receiving from 10 to 20 inches of rainfall per annum. This area, which includes Griqualand West, the Western half of the Free State and the Cape Midlands, comprises 27½ million morgen and in 1936-37 supported 3,084,000 livestock units.

3. Sub-humid area, receiving from 20 to 30 inches rainfall per annum. This area includes portion of the Northern Transvaal, the Transvaal and Free State high-veld areas, a portion of the Eastern Province and the South Western Cape and amounts to 24 million morgen, supporting in 1936-37, just over 5 million livestock units.

4. Humid area, receiving over 30 inches of rainfall per annum. In this area, which includes the Eastern mountain grassveld areas of the Transvaal, Natal and a portion of the Eastern Province, 11¾ million morgen, in 1936-37 supported over 3 million livestock units.

### Total Livestock Population.

European holdings in the better watered section of the Union, i.e., the sub-humid and humid areas thus comprise over 35¾ million morgen, which support just under 8¼ million livestock units, including native stock on European farms. This gives an average carrying capacity of one livestock unit to 4·3 morgen of veld. Full allowance has been made for the actual areas under crops and forests and also for the land under dwellings and farm buildings. In the drier section of the Union, 56¾ million morgen support rather more than 4 million livestock units, giving an average carrying capacity of one livestock unit to 14 morgen of veld.

For the sake of convenience, from now on, I shall refer to the sub-humid and humid areas as the high-rainfall area, and the arid and semi-arid areas as the low-rainfall area.

Native Reserves. With regard to the reserves, it has not been possible to ascertain the exact areas, but according to Jones, the amount of land owned by natives at the time of the 1936 Act was 10,410,000 morgen. If we add the areas owned by natives in the released areas and in European areas, we get a total of 11,360,000 morgen. On this area there were maintained, according to the 1936-37 Census, some 4,072,000 livestock units. As the Census does not give the age groups of livestock in the reserves, it was considered accurate enough for the purposes of this address, however, to assume that the age composition of native livestock was the same as that of European owned stock. The factors suggested by Clarke were therefore used in arriving at the above figure.

Although most of the native reserves fall in the high-rainfall area of the Union, there are several in the Northern Cape, in the districts of Mafeking, Kuruman, Taungs and surrounding regions. The total area of these and their livestock population are not known, but it was thought fair to assume that in the high rainfall area of the Union, about four million livestock units were maintained on 11 million morgen. From this area must be substracted the land under cultivation and that covered by dwellings and other buildings. This can hardly be less than one million morgen which means that the reserves were stocked at the rate of one livestock unit to $2\frac{1}{2}$ morgen.

Combining these two sets of figures, we find that in the high rainfall area of the Union, there are roughly $12\frac{1}{4}$ million livestock units on about 46 million morgen of veld. It will be readily appreciated, therefore, that the veld in the high rainfall area is one of our most important agricultural assets, and it is probably fair to say that a substantial proportion of its enormous livestock population must obtain practically all its nutrient requirements from the natural grazing. It is true that the veld is helped in this task of sustaining its animal population by 138,000 morgen of teff, 41,000 of other cultivated grasses, 13,000 of spineless cactus and saltbush, 102,000 of lucerne, as well as the aftermath grazing of crop lands, but in relation to the amount of feed required, this assistance is far too small to prevent heavy losses of liveweight in winter, and excessive stock losses through starvation in many parts, particularly in bad seasons. In fact, Hall has estimated that in 1934, our flocks and herds could have subsisted for only 40 days of the winter on all the supplementary feeds then available.

### Treatment of the Veld.

In view of the importance of our pastoral industries, it is pertinent to enquire, therefore, what treatment is meted out to our veld. The answer is that, except for very small areas under the control of a few enthusiasts, our veld, by and large, is given no treatment at all. Burning is done indiscriminately, grazing is badly controlled or not controlled at all, so that over or undergrazing are usually taking place and, so far removed are we from the idea of restoring or improving the fertility of our soils under veld, that those who suggest fertilising veld, are regarded with suspicion. The result of our attitude towards the veld in general may be summarised in the words of the Industrial and Agricultural Requirements Commission, which states in the review of our agricultural resources contained in its third report that "at present, improper pasture management is resulting in an almost general deterioration of natural grazing, culminating in further denudation and moisture loss. Thus, what should be the most durable of the Union's natural resources is being dissipated extensively and at a cumulative rate."

If a national policy is to be evolved, it is imperative that problems of veld management should be investigated at more centres and in more of the distinctive veld types than is now the case, and when once new information is available, more effective machinery must be devised to ensure that these findings are put into practice by farmers. For instance, as far as burning of veld is concerned, much valuable information has been accumulated, but with few exceptions farmers who burn their veld are guided by little but whim or custom. Thus, it is not uncommon for farmers in many parts to burn veld in the growing season to provide fresh green grass for late summer grazing, although this has been shown to be a most deleterious practice. It is certainly less work than making hay in the summer or growing oats or other winter cereals for grazing, but its effect on the better species of veld grasses is ruinous.

Again, the mowing of veld in place of burning or as a valuable aid in veld management, needs emphasis in many areas. Admittedly there are large tracts of rocky and mountainous veld which can never be mown, and other extensive areas where scrub and bush would prevent mowing unless clearing or thinning were undertaken. Nevertheless, it must be one of the important points of a national pastoral policy, that mowing of veld be encouraged wherever possible for the control of grazing and conservation of the summer surplus of grass. This topic will be referred to later.

The spreading of thorn trees is allowed to proceed practically without check and is a serious matter in various parts of the country. Research into this problem is urgently needed and should be generously financed, in order that the proper balance between grasses, shrubs and trees may be determined, and methods of maintaining this balance evolved and put into practice. The area of veld involved is so great that thinning out the bush on a large scale might well be given attention when the post-war re-employment problem is being considered.

### Agro-Economic and Regional Surveys.

The management of grazing, as Irvine puts it, entails "adequate provision for the grazing animals at all seasons of the year, and at the same time the securing of stability or gradual improvement of pasturage." It will be readily admitted by most farmers that at certain times of the year, usually in early summer, there is more grazing available than the stock can consume, but for the rest of the year the animals can barely maintain their weight, and, in winter, unless supplementary feeding is resorted to, they steadily lose weight. In a bad season, or when spring rains are delayed, stock losses assume alarming proportions, mainly through starvation. Thus in the 1936-37 season, which was by no means a bad one, stock losses in the high-rainfall area alone totalled 890,000 livestock units

or 7·27 per cent. of the livestock population. In the European areas 495,000 livestock units or just under 6 per cent. were lost, while in the reserves 355,000 units or 8·9 per cent. were lost. In the low rainfall area total losses were 234,000 or 5·7 per cent. of the total population. We should no longer look with equanimity on these heavy losses which occur year after year, even in good rainfall seasons.

It will be difficult to remedy this state of affairs over the country as a whole until the various types of veld have been mapped in greater detail and the potentialities of the different types have been assessed over a period of years.

In this connection, the Agro-economic survey of the Union, now being conducted by officers of the Division of Economics and Markets, is a step in the right direction, although the whole basis of their survey should be broadened by including animal and field husbandry officers, as well as pasture research officers in the team of investigators. This would result in a scientific appraisal of the physical resources of a region and there would be less emphasis on the financial aspect of current farming systems. Given this information, we should be able to make plans for the future of agriculture on a much more reliable basis, for we would know more about the productive possibilities of the different parts of the country and consequently how to preserve and improve rather than waste our assets.

When once we have surveyed the whole country in this way, we shall have a better idea of the potential carrying capacity of various types of veld and, what is perhaps of even more importance, we shall be in a position to establish some controlling body or bodies to keep in touch with agricultural developments in various districts and, if need be, to take action to regulate grazing and stocking in the interests of the country as a whole.

In the United States of America, bodies of farmers have been formed to control erosion in certain areas and these bodies have been endowed with the necessary legal authority to enforce their decisions. In South Africa, such bodies might be farmers' associations in a typical veld area or public servants responsible to the Division of Soil and Veld Conservation, but, however constituted, they must have some power to enforce the decision of the majority of the farmers. Public opinion must be behind them in a firm resolve to prevent at all costs the destruction of our veld.

In formulating a national grazing policy, we must have the courage of our convictions and see to it that no distinction is made between veld belonging to Europeans and veld belonging to natives. In the long run, it will do us no good to maintain and preserve the veld under European control, while scattered widely over the country, native locations and even municipal areas and town lands are being steadily ruined. If it is admitted

that the veld in European control in the high-rainfall area of the Union is deteriorating in many parts under a rate of stocking of 4·3 morgen per livestock unit, what must be happening in reserves where from 1·6 to 2 morgen are available per unit? On one small mission farm in Natal, less than half a morgen is available per unit.

The situation, admittedly, bristles with difficulties, not the least of which are the traditional Bantu outlook with regard to stock and the European belief that in some miraculous way denudation, destruction and erosion in reserves will have no harmful effect on European areas, but will, on the other hand, serve to augment the supply of native labour. Happily there are signs that both views are changing, and if this problem is tackled with courage and determination, the veld may yet be saved.

## Grazing Control.

From what has already been said, it should be clear that even when we have information about the areas and composition of the various veld types, upon which to base a national grazing policy, it will be essential to ensure much better utilisation of the herbage than has been the case in the past.

Without some means of sub-dividing the grazing areas, the farmer cannot exercise the control essential to the efficient use of the veld. As far as South Africa is concerned, that means of sub-division and control is fencing. The grazing of veld types in smaller units; grazing at times best suited to different veld types; resting and protection of pastures—in fact, the intelligent management and efficient use of our grasslands depend ultimately on reliable stock-proof fencing.

In my opinion, the provision of fencing is one of the fundamentals of a national pastoral policy and the amount of materials required is so large that the question of establishing new factories and encouraging existing factories to increase the production of fencing materials might well be considered as a factor in a post-war re-employment programme.

It is difficult to estimate with reasonable accuracy the amount of fencing required by the country as a whole, but the following figures are submitted in the hope that some idea may be gained of the magnitude of the amount of material involved.

In the first place, trade and shipping returns for the period 1935 to 1939 show that our annual imports of fencing material ranged from 9,000 to 17,900 tons of barbed wire, 12,000 to 18,900 tons of plain fencing wire, 13,000 to 25,000 tons of standards and posts, and 3,000 to 5,250 tons of droppers. On the basis of four strands of wire in a fence and 700 yards of wire in a 100 lb. coil, the largest importation of barbed wire, namely 17,900 tons would allow the erection of over 35,000 miles of fencing. If all the plain fencing wire were used in the same way, our pre-war imports would have made possible the erection of up to 70,000

miles of fencing per annum. Of course, much of this wire was used in urban areas and for other than fencing purposes, so that in the immediate pre-war years, we probably erected something like 25,000 miles of fencing on farms every year.

### Amount of Fencing Required on Farms.

In order to obtain some idea of the fencing that would be required to subdivide farms according to improved methods of veld management, a rough calculation of the perimeters of farms with the minimum number of grazing camps in a given area has been made. The provinces of Natal and Transvaal were selected, as both fall within the high rainfall area of the Union, and the average area of farms in each of the categories given in the 1936-37 Census was determined. Assuming all farms to be square, the length of the side for the average farm in each category was computed. Then allowing from 2 camps each for farms of from 5 to 20 morgen up to 18 for ranches of 10,000 morgen and over, it was estimated that the minimum fencing requirements for these two provinces would be some 498,000 miles.

Those portions of the Orange Free State and Cape provinces falling in the high-rainfall area are together probably less than half the area of the two provinces taken above and hence their fencing requirements on the same basis would be about 250,000 miles. The total for the high rainfall area is therefore at least 750,000 miles of fencing. Now, if we assume very generously that half the farms in this area are already adequately fenced, and the remainder already have half the fencing they require, we would still need at least 187,000 miles of fencing in the high rainfall area of the Union.

In the low-rainfall area of the Union, where farms are larger and, owing to the lower average carrying capacity, grazing is on a more extensive scale, the fencing requirements would be much lower than in the high-rainfall area of the Union. Furthermore, in certain sections, where sheep farming predominates, much jackal-proof fencing was erected prior to 1939. Nevertheless, this area probably requires as a minimum 500,000 miles of fencing and, making the same assumptions as previously, we arrive at a total of 125,000 miles for this area. In all, I estimate that European farms in the Union require at least a further 300,000 miles of fencing in order to ensure some degree of control over the grazing. When eroded areas, which should be fenced until a vegetative cover is re-established, and the thousands of miles of dongas which should also be protected from stock, both in native and European areas are included, it will be seen that our requirements of fencing from the point of view of veld conservation alone must be well over half a million miles, without making any allowances for material required for replacement of existing fences. Even if we accept the lower figure of 300,000 miles, it means approximately 150,000 tons of barbed

wire, 230,000 tons of standards and posts, and 56,000 tons of droppers. These amounts are so large that I would suggest the adoption of a five-year plan in which from 50,000 to 60,000 miles of fencing could be erected per annum. The financing of such a plan could be effected either by means of fencing loans on attractive terms, or by means of a subsidy for approved fences erected within a specified period. No matter how the scheme is finally brought into being, our watchword must constantly be more fencing to save the veld. Along with more fencing must go education in pasture management for the camping off of the veld cannot by itself maintain or restore it.

## Conserving and Improving the Fertility of Our Soils and Pastures.

Although it is agreed by most people who have given the matter any thought that South Africa is not a rich country—agriculturally speaking—our soils, poor as they are, are nevertheless being exploited and, as far as the veld is concerned, the question of maintaining, let alone improving fertility, is seldom considered. Before going on to deal with the subject in more detail, it may be worth while to turn for a moment from the traditional outlook of the average South African farmer towards his veld, which is to look upon it as a gift of Nature, requiring nothing from him in return and examine some modern trends with regard to fertilisers and soil fertility. This will serve to place the subject in its proper perspective.

The period 1941-42 marked two most interesting centenaries and, had it not been for the war, most agricultural workers and scientists would have freely acknowledged their importance.

In 1842, John Bennett Lawes took out a patent for the manufacture of superphosphate from mineral phosphates. The only source of phosphatic fertilisers prior to that time had been bones, either freshly ground or burnt. By 1862 the annual production of superphosphate in England had risen to 200,000 tons, and, by 1937, world production had reached a total of 16,868,000 tons, of which it was estimated 16,564,000 tons were actually used in that year.

The second is also a fertiliser centenary for, although sulphate of ammonia in the form of gasworks residues had been used in the liquid form in the first two decades of the 19th century, it was not until 1841 that the first authentic experiment with this product was recorded in Scotland. In 1849, it was reported that a considerable number of farmers were using sulphate of ammonia, and, by 1870, the production of this material in Great Britain had risen to 40,000 tons per annum. By 1900, the world use of nitrogen had raised the production of inorganic nitrogenous fertilisers, such as sulphate of ammonia and nitrate of soda, to 300,000 tons per annum, and it has been estimated that by 1936 world consumption of nitrogenous ferti-

lisers had risen to just over 12 million tons containing 2,214,000 tons of nitrogen.

In this connection a point of great importance is that in 1900, Chilean nitrate of soda accounted for 66·6 per cent. of the inorganic nitrogen used, distillation of coal 33·4 per cent., while none was obtained from the air. By 1913 Chilean nitrate had dropped to 55·4 per cent. of the total inorganic nitrogen used, coal had increased to 37·3 per cent., and 7·3 per cent. was obtained from the air. By 1934, nitrate of soda had dropped to 6·9 per cent., coal to 18·6 per cent., and production from the air had gone up to 74·5 per cent. of the total. The significance of this revolution in the production of inorganic nitrogenous fertilisers can hardly be over-emphasised, since it has been estimated that there are 20 million tons of nitrogen over every square mile of the earth's surface and hence the supply of the primary raw material is, practically speaking, inexhaustible. The technique of "fixing" atmospheric nitrogen having been developed, the dream of an age of plenty has now become a possibility.

Now, in view of the increasing world output and use of nitrogenous and other fertilisers, we may ask about the position of our veld and the pastoral industries it supports which, according to studies of the National Income, at present account for a net value of about £30,000,000 a year. The answer is, that of the fertility which is being withdrawn every year, very little is being put back by man. Neilson pointed out in 1931 that over a five-year period, the average annual loss to the veld in pastoral products exported, i.e., quite apart from those consumed locally and from all arable production, was over 13,000 tons of nitrogen, 709 tons of phosphoric oxide and over 6,000 tons of potash. During this same period only 2,976 tons of nitrogen were imported, hardly a ton of which, it is safe to say, was applied to the veld. Our average annual imports of phosphoric oxide were 37,000 tons, and of potash 4,550 tons, but these fertiliser constituents were applied almost entirely to agricultural crops and not to natural pastures.

It may be claimed that, under natural conditions, there must have been an equilibrium in which the return of nutrients to the soil balanced the production of grasses, herbs, shrubs and trees. This is probably true, but conditions have changed, however, and can no longer be considered " natural." With modern ways of life there is now a constant flow of pastoral products away from the land to the cities and even overseas. Although the manure and urine of animals return to the veld, and every year about 10 lb. of nitrogen per morgen come down in the rainfall, there is still a loss of nitrogen from the solid part of the manure, and the nitrogen and minerals in animal products such as meat, milk, cheese and wool are, for the most part, lost to the veld.

Lipman and Conybeare, in the United States of America, estimate there is a net annual loss in that country of 6·65 million

tons of nitrogen, notwithstanding gains of 5·46 million tons due to symbiotic fixation, 4·37 million tons due to non-symbiotic fixation and 3·38 million tons from rainfall and irrigation. Very little information is available as to the amount of nitrogen fixed by thorn trees or other legumes in the veld in South Africa, nor do we know definitely what amount of nitrogen is gained by non-symbiotic fixation, so that it is not possible to present an accurate balance sheet with regard to this element. However, when we consider the amount of nitrogen in pastoral products exported prior to 1939, and the consumption of these products in the Union, it would probably not be very wide of the mark to estimate a loss to the veld of at least 100,000 tons of nitrogen a year. As a check on the accuracy of this estimate, we may note that Clarke has calculated a livestock unit weighing 1,120 lb. requires 136 lb. nitrogen per annum for maintenance alone, i.e., a total of some 833,000 tons of nitrogen for the livestock in the high-rainfall area of the Union. Subtracting from this the 230,000 tons that come down in the rainfall, we find that over 600,000 tons have to be provided by the grass from the soil. If only a quarter of the nitrogen taken in by stock is not returned in the form of manure and urine, then no less than 150,000 tons of nitrogen must be taken from the veld each year for livestock maintenance. The production of milk, meat, cheese and wool, the work of draft animals and the growth requirements of young stock must increase this amount considerably.

If this reflects the true position with regard to the veld, we may ask what can be done to restore the fertility of our soils under pastures. One of the first things that comes to mind is the encouragement of clovers and other edible legumes. In practice, however, this does not offer very much relief, as our soils lack phosphates and many of them are very acid. Our climate also, with its alternating wet and dry spells in the hot summer and a cold, dry winter, is not one under which clovers thrive. In moist low-lying areas, clovers might be encouraged, but in the aggregate the amount of nitrogen fixed by this means must remain small in relation to the total amount required to offset nitrogen losses.

We are thus forced to the conclusion that South Africa ought to come into line with other countries which now draw freely on the atmosphere for their nitrogenous fertiliser requirements. There is evidence that this country is awakening to the great need for nitrogen, for our imports of sulphate of ammonia, principally for fertilisers, have risen steadily from 1,376 tons in 1927 to over 15,000 tons in 1939. Nitrate of soda imports for agricultural purposes, although small, also increased over the same period. Up to 10,000 tons of bone fertilisers were also imported annually up to 1939. This is all to the good, but it must be admitted that, although some fertilisers containing nitrogen may have been applied to improved pastures and fodder crops fed to stock, practically nothing has been applied to the veld.

This brings us to the main argument of this address which is that, unless we change radically our attitude with regard to the veld and consider it in every way as deserving of our attention as agricultural crop lands, and hence become willing to fertilise it liberally with nitrogenous fertilisers, we will be neglecting one of the most important factors in our internal economy—one, moreover which could put our pastoral industries on a sound footing, help materially in preventing erosion and enable us to feed all our people adequately.

Not only must we make good the losses from veld, but we must look upon the veld as a medium for the conversion of inorganic nitrogen into forms of protein required by livestock, for grasses are pre-eminently adapted to making use of large quantities of available nitrogen and converting it into nutrients.

Investigations carried out by Hall and members of his staff since 1930 have shown that our veld responds, as do the grasslands of other countries, to applications of nitrogen. Considerations of time do not permit of this work being dealt with in detail, but some salient points may be given to indicate briefly the results that have been obtained. Thus the application of 600 lb. sulphate of ammonia per morgen in three dressings, along with phosphates and potash has, firstly, doubled the carrying capacity for the summer grazing season, six animals being maintained on four morgen as against three on four morgen receiving no fertiliser. The average annual liveweight gain over four seasons was increased from 131 lb. to 419 lb. per morgen. In addition, there was some surplus herbage produced on the fertilised veld which, though not consumed in summer, when mown, cured and stacked, was readily eaten in winter. This production was obtained on what would be considered poor, sour veld on an acid sandy loam deficient in phosphoric oxide, nitrogen and potash.

Hay yields from the same areas in a subsequent season showed that the unfertilised veld produced 1,716 lb. per morgen, whereas the fertilised veld produced 4,824 lb. containing 42 lb. nitrogen. The nitrogen content of the unfertilised hay was not determined, but even if it were as high as that of the fertilised grass, which is doubtful, the yield would have been only 15 lb. per morgen.

It is thus clear that the application of 600 lb. sulphate of ammonia per morgen increased the carrying capacity of poor veld from three animals per eight morgen for the whole year to six per eight morgen or up to three animals per four morgen. As the average carrying capacity for European farms in the high-rainfall area is one livestock unit per 4·3 morgen, it is obvious that wherever we can fertilise we can at least double the carrying capacity. Lest this be taken as a possible cause of overstocking, I hasten to add that in our fertiliser treatments the grass cover increased in density and, although there have been botanical changes such as an increase in Eragrostis species,

production of weight increases has been maintained and surplus herbage ungrazed in summer has been readily consumed in winter. Fertilising the veld will thus help to prevent erosion by improving the grass cover and will not lead to overgrazing unless, of course, it is accompanied by mismanagement.

With regard to the potential use of nitrogenous fertilisers in South Africa, it is easy to speculate and arrive at astronomical figures involving millions of tons. The farmer has to be convinced, however, that fertilising will pay and the price of nitrogenous fertilisers will have to come down considerably before much progress can be made. Prior to 1939 the trend of prices for nitrogenous fertilisers was downwards all over the world, and it is to be hoped that before long, this trend will be in evidence again and the rate accelerated. More important even than the provision of cheap fencing, I look upon cheap nitrogen as the crucial factor in our pastoral economy.

So great are the benefits to be derived from the liberal use of nitrogenous fertilisers, that we must increase our consumption and put to good use all the by-product ammonia from coal that is being or may be produced in this country. After the war we should take advantage of increased production of nitrogenous fertilisers in other countries which will possibly be available at reduced prices. Eventually, as consumption increases, it may be necessary and desirable to undertake the production of synthetic nitrogenous fertilisers in South Africa. If every European farmer in the high-rainfall area of the Union could fertilise one-tenth of the area of his veld at the rate of 600 lb. per morgen, it would mean increasing the carrying capacity on 3½ million morgen from 800,000 to 1,700,000 livestock units, besides providing better grazing for the increased numbers. A programme of this nature would involve an amount of over a million tons of sulphate of ammonia or nitrochalk. As our fertiliser consumption mainly for arable crop production has reached a total of almost 400,000 tons per annum, including about 15,000 tons of inorganic nitrogenous fertilisers, the fertilising of pastures may well bring about a trebling of the total amount consumed.

The use of nitrogenous fertilisers is not recommended in the low-rainfall area, except perhaps on irrigated lands, as farming is on too extensive a scale and the climate in general is such as to preclude economical returns from applications of fertilisers. It is essential, however, that a careful study should be made of the veld in this area so that it may be soundly managed and utilised in the best possible way. This might involve more fencing and an increased use of a complete rest for a season or more in rotation.

To give one-tenth of the native areas 600 lb. sulphate of ammonia or other nitrogenous fertiliser per morgen would require an amount of 300,000 tons per annum. In these areas it would do relatively more good than in European areas for the

pastures in the reserves are consistently over-grazed and the grass is always short. In fact, it would be to the lasting benefit of the country as a whole if as great a proportion of the native reserves as possible could be fertilised, thereby increasing the density of the grass cover and greatly augmenting the production of foods of animal origin, especially milk, for the inhabitants of these areas.

### Phosphates, Potash and Lime.

With regard to dressings of phosphate, our experiments have shown that the average phosphoric oxide content of the herbage can be increased from 0·17 per cent. to 0·29 per cent. by means of annual applications of 400 lb. rock and superphosphate mixture per morgen, but the application of phosphatic fertilisers by themselves does not give returns of sufficient magnitude to make it profitable. An average content of 0·30 per cent. $P_2O_5$ in the herbage is low compared with that found in other countries. but the animals in our experiments appear to have thrived and never to have consumed much phosphatic lick, although it was always available.

As pasture grasses will not make the best response to nitrogenous fertilisers unless some phosphate is applied, however, we should consider applying a phosphatic fertiliser, say, at least once in three years to the veld. This should make it unnecessary to feed bonemeal on such veld for the greater part of the growing season. As most farmers seem to find the practice of feeding bonemeal inconvenient, fertilising the veld may prove to be an easier way of preventing phosphate deficiency. Fertilising one-tenth of the veld, both native and European, in the high-rainfall area at the rate of 400 lb. superphosphate once in three years, which is about the minimum if worthwhile results are to be expected, would require the application of 320,000 tons annually.

With regard to potash, the evidence thus far obtained indicates that our soils are fairly well supplied with this fertiliser constituent, and on veld, at least, no significant increase is brought about by its use. For the time being, therefore, we may conclude that no potash need be applied to the veld.

As far as lime is concerned we know that, although grasses will thrive on both acid and alkaline soils, they nevertheless do respond to lime applications on acid soils. We should keep in mind, therefore, the possibility that liming may be beneficial on many of our poor veld areas and that, if sulphate of ammonia is used on a large scale in the future, applications of lime will be necessary from time to time to prevent the soil becoming unduly acid. Liming will also encourage the development of clovers where the climate is suitable.

It is not necessary at this stage to work out the amount of lime that might profitably be used, as the needs of our grasslands for nitrogen and phosphorus are relatively much greater

than for lime and our immedate task is to see that these two plant food elements are supplied.

### Compost.

At the present time, when fertiliser supplies are limited, attention has been diverted to the provision of substitutes and we are now witnessing an intensive campaign having as its object the conservation of all organic wastes and their conversion into compost. This is a laudable objective, but there are a few points in connection with compost manufacture that should be kept in mind. It has been shown in numerous experiments, for instance, that in composting there is a loss of carbon as carbon dioxide and usually of nitrogen as ammonia. The loss of nitrogen is usually estimated as being about 15 per cent., while that of carbon may rise to 50 per cent. Composting, therefore, does not add to the amount of nitrogen "in circulation" as it were, although it does reduce the waste of organic matter. A second point is that compost manufacture has a high labour requirement, particularly if it has to be turned one or more times. This will limit its usefulness, for our aim must be to reduce the labour requirements of our agricultural activities and replace hand labour wherever possible by machinery. Careful check must be kept on the costs of compost, as it seems easy to over-emphasise its valuable qualities and see in them something almost magical and lose sight of the fact that the plant nutrients it contains may be costing us more than they are worth.

A final point is that if compost is applied to permanent grasslands, the loss of nitrogen to the atmosphere and the resultant low recovery of nitrogen in the grazing or hay will make its use uneconomic. The application of compost to land being prepared for pastures or arable crops, where it can be ploughed in immediately, is, on the other hand, to be strongly recommended. The utilisation of waste straw, damaged hay, surplus grass and waste silage to enrich our arable lands and increase their yields is a sound farming principle provided that the cost can be kept within reasonable limits. In actual practice it will usually be found that when it comes to a question of applying 20 tons per morgen over an appreciable area, handling and transport problems become too difficult for the average farmer.

### Supplementary Grazing.

This brings us to the question of the treatment of our supplementary pastures, which were mentioned earlier in this address. A vigorous campaign for the popularising of what the census terms "other cultivated grasses" has been carried out for some 14 or 15 years, but the total of 41,500 morgen for the whole Union in 1936-37 is disappointingly small. This is probably due to several factors, of which the most important are: that many of the grasses recommended, particularly those of the Woolly

Finger family, set little or no viable seed, and hence pastures have to be planted from roots or stolons; without adequate fertilising or manuring, the yields, particularly after the first season, are often inferior to those given by the veld; and, lastly, most introduced or cultivated grasses need careful management.

With regard to yield, our experiments have shown that, at the 600 lb. sulphate of ammonia to the morgen level, veld grasses can outyield a Rhodes grass and Paspalum dilatatum mixture on a poor sandy soil which has developed on granite, as regards both total yield and crude protein production. This should not be taken to mean that these cultivated grasses have no place in our pastoral policy, for most of them are very palatable, give good yields when adequately fertilised, and often give grazing at times when the veld has gone off or is dormant.

The fact that most cultivated grasses have a high fertility requirement is illustrated by the two following examples:—On one occasion a Rhodes grass and Paspalum dilatatum pasture was looking very poor and yellow in early December, so some small blocks of plots were put down and given various amounts of sulphate of ammonia up to 2,000 lb. per morgen in a single dressing. Forty-two days later the plots were harvested and increased yields of dry matter and nitrogen, corresponding closely to the amounts of fertilisers applied, were recorded. Thus, the no extra nitrogen plot yielded 1,272 lb. dry matter per morgen, containing 13 lb. nitrogen, while the 2,000 lb. sulphate of ammonia dressing produced nearly five times the amount of dry matter containing nearly seven times as much nitrogen.

The other example of high potential yields on cultivated pastures came to light during the past season when a road between two blocks of camps was fertilised three times to encourage a grass cover and control erosion. Where contour banks discharged storm water in the camps, most prolific growth occurred. Investigation showed that the different mixtures of grasses were giving up to 17·3 and 19·5 tons dry matter per morgen in two cuts, containing up to 527 lb. nitrogen. In other words, when moisture is not a limiting factor and plant food is available, pastures on poor sandy soil can produce up to 3,200 lb. crude protein per morgen.

It is clear, therefore, that supplementary pastures could be fitted into a national pastoral policy, and, as they must always be established on land that can be worked, they could be grazed at certain times and mown for hay or ensilage at others. With adequate fertilising, high yields of nutritious herbage could be expected.

Before leaving this section, a few words on the cultivation of teff may not be out of place. The popularity of this crop in the Union is somewhat difficult to understand, for it is an annual—is not particularly palatable, and is not a heavy yielder.

The annual ploughing and working of the soil for this crop must inevitably result in erosion and soil depletion and a high cost of production. It should be part of our pastoral policy to encourage seed production of grasses such as Rhodes grass and Paspalum dilatatum so that good seed is available at reasonable rates. Farmers should then be urged to substitute for the annual teff crop, leys of three or four years of a mixture of these two grasses, which would provide high yields of good hay and also some grazing. At the end of three or four years, when the ley is ploughed up, the soil will be in a much better state than after a teff crop.

### Irrigated Pastures.

The potential yields of sown pastures already mentioned should make it clear that irrigation settlements could produce enormous quantities of hay or keep large numbers of stock when nitrogenous fertilisers become plentiful and cheap. If hay is produced, they would serve a most useful function by acting as sources of supplies of feed when other parts of the country are suffering from drought. The inclusion of intensively grazed and fertilised leys in the rotations of irrigation settlements will also have a most beneficial effect on the soils of these areas, especially as overseas experience indicates that pasture mixtures can withstand fairly high salt concentrations in the soil.

### The Mechanisation of Our Pastoral Industry.

The proper development of our pastoral industries demand that all our livestock must be fed adequately throughout the year. If we accept this dictum, and also the fact that in most parts of the high-rainfall area, the grazing during autumn and winter and often in early spring, is of low or reduced feeding value, then we must make provision for feeding our animals during these periods. The fact that so little feeding is done in winter and so little provision made for droughts, betokens a sublime faith in the reliability of the rainfall and an optimistic idea of the feeding value of our pastures in winter, which recurrent droughts and losses in condition should by now have dispelled.

One of the most serious obstacles to the development of our pastoral resources is our dependence on hand labour and our lack of suitable machinery for the essential operations of mowing and making hay and ensilage.

It is this dependence on hand labour that makes us keep such a large proportion of our population on the land—a proportion which reaches the extremely high figure of 66 per cent. when natives in the reserves are classed as agriculturists. The only remedy for this, in my opinion, is to increase the efficiency of our agricultural operations, first of all by increasing the tempo of agriculture. This means that, for a start, we should critically examine the efficiency of ox traction and by using more horses

and machinery, relegate the ox to the position for which it is best fitted, namely, the production of beef. Then we must use a much greater amount of machinery to increase the output per agricultural worker, while at the same time reducing the number of workers.

How far we are from possessing enough machinery for pastoral farming may be gauged from the following figures gathered from the 1936-37 Census. The enumeration of that year shows that in the Free State and Natal roughly one farmer in two has a mower and even fewer farmers have hay rakes. In the Cape Province and Transvaal one farmer in three has a mower and about one in four a hay rake. These figures are worked out on a basis of farms of 21 morgen and over, as it was considered these implements could not be used efficiently or would not be used at all on holdings of 20 morgen and under.

Altogether in the high-rainfall area of the Union there are roughly 58,000 holdings of 21 morgen and over, and on these in 1936-37 there were only 21,600 mowers and 17,000 hay rakes. Thus considerably less than half our farmers could cut hay if they wanted to, except by hand with sickles, and less than one farmer in three could rake it, even if he cut the grass. If holdings of from 6 to 20 morgen are included, the position is, of course, much worse.

Trade and shipping returns do not distinguish between binders, reapers and mowers, but they show that the largest number of these implements imported was in 1925 when the total reached 5,138. In the years prior to the war, up to 1939, the number imported annually was between 4,000 and 5,000, so that the number of mowers purchased each year by our farmers was probably below 4,000. This number of mowers will obviously not permit of a rapid expansion of hay and ensilage production.

It will be clear from what has already been said that a progressive programme will call for an enormous increase in the amounts of hay and ensilage made. Thus, to give 12½ million livestock units 15 lb. of hay a day for four months would require over 11 million tons of hay. In this connection it is proposed that by far the greater part of these two products should come from the veld or introduced pastures and not from arable lands. It is usually claimed that our summer weather is unsuitable for hay-making, and so this operation is usually delayed until the grass has practically matured and its protein content has dropped considerably. The real reason is probably not the weather but the slowness of the process, for we must remember much good hay is made in England, Scandinavia, New Zealand and other countries with climates more humid than our own. However, if the weather is unfavourable and hay cannot be made, fairly good ensilage can be made from grass, provided some care is devoted to the process.

How far we are removed from an appreciation of the value of ensilage in pastoral agriculture is shown by the following figures. According to the 1936-37 Census, only 4,100 farmers out of about 50,000 in the high-rainfall area had pit or trench silos, which, after all, are nothing but excavations in the ground and are easy to excavate at a low cost and only 1,150 farmers or one in forty-three had a tower silo. The total amount of ensilage of all kinds made in the high-rainfall area in the same year was 182,000 tons or sufficient for a ration of 44 lb. a head for 8¼ million livestock units for just one day.

## Our Machinery Requirements.

If we are to cut enough hay and make enough ensilage to feed our livestock adequately, then it is clear we must increase the number of mowers in use. It has been estimated that for the proper control of veld, a mower is required for every 50 morgen. This would mean that for the same area of veld that is fertilised, namely one-tenth of each farm, 70,000 mowers would be required—that is, an increase of 49,000 on the present numbers. Actually, it would probably be found in practice that for the best results, every farmer with 50 morgen or more of mowable veld should have at least one mower. At this rate we could, with advantage, quadruple the number of mowers at present in use.

After the grass has been cut it has to be raked up into windrows and at present this process also is a very slow one. A great improvement in the speed of this operation could be effected by the use of side delivery rakes drawn by horses or tractor. This implement moves faster than the rake and turns the swath over and leaves it in rows paralled to the direction of the cut. For drying hay, the side delivery rake is much superior to the ordinary type as the rows can be turned over and moved as often as desired. Moreover, the hay is left in a loose condition in the windrows, which facilitates curing.

When the hay has dried in the windrows, a saving in time and labour could be effected by loading it directly on to the wagon from the windrow by the use of the hay loader. Here again, the wagon would have to be drawn by horses or a tractor for the best results, as the pace of the ox is too slow and jerky for efficient loading.

When once the hay has been loaded on the wagon and has been brought to the shed or barn or to the place where it is to be stacked, time and labour could again be saved by the use of grabs and loading and stacking devices.

In a survey of the efficiency of different methods, it was found that three men loading and unloading a wagon by hand could stack 2·93 tons of hay per adult worker per diem. When the wagon was loaded with a loader and unloaded with a stacker, the work could be done by two men and a boy, and each adult worker stacked 5·87 tons in a day.

In the making of ensilage the grass does not have to be dried, and hence it can be raked and picked up as soon as possible after cutting. The process here can be speeded up by the use of side delivery rakes to put the crop into windrows, and sweeps to bring it to the silo or the wagon. Sweeps are widely used in New Zealand and Australia for rapid handling of large amounts of green grass. When grass is preserved as ensilage in a pit or trench silo, it is usually unnecessary to cut it. All that is required is to bring it to the side of the pit or through the trench and offload it from the wagon. When it is put into a tower silo it will be necessary to use a cutter and blower.

Before concluding this section, the question of fertiliser spreaders must be given some attention, for if the veld is to be fertilised it cannot be done by hand. Nitrogenous fertilisers should be spread when the ground is moist, and hence the best and safest time to spread on a large scale is after a good rain. At this time spreading should be rapid, and for the best results a spreader should be used. Horse-drawn spreaders would accelerate the process, while the use of a tractor would enable the ground to be covered with even greater speed. The ideal, however, is the type that has been developed in Australia, in which a spreading device is attached to or may even be a part of a vehicle, similar to a lorry, which is able to carry one or two tons of fertiliser. If the job is to be done, it will be necessary for each farmer to be able to spread at least 15 to 20 morgen a day with one spreader.

We know so little about the potentialities of these implements and labour-saving devices under South African conditions that it is difficult to estimate the actual number of hay rakes, loaders, sweeps, stackers and fertiliser spreaders required, but if every farmer on the 58,000 holdings in the high rainfall area had one each of these implements, a great step forward in the control and utilisation of our veld would be possible. As a rough approximation, it would probably not be very wide of the mark to estimate that from 20,000 to 30,000 of each of the above items would be required before a really progressive pastoral policy could be put in motion.

The amount of machinery required in the native areas is difficult to assess, for in most parts there is little surplus grass to cut for hay. The need is great, however, and the example of Malietzies location quoted by Hall, where 12 mowers are used to cut hay for winter, could be multiplied many times to the advantage of the native people and their stock. It seems reasonable to estimate that the various native communities should be in possession of at least 1,000 mowers and 1,000 hayrakes, which would enable about 50,000 morgen or more of veld to be cut for hay. As the veld improves and the native peoples progress, other implements, particularly fertiliser spreaders, could be obtained and used.

Considering the large numbers of implements required for the country as a whole, it appears a good case can be made out for the establishment of implement factories in the Union to cater not only for the needs of a pastoral industry based on an efficient utilisation of the natural herbage, but for arable agriculture as well. This would provide employment in manufacturing industry, while the number of agricultural workers could be reduced as machinery becomes available for farm operations.

## CONCLUSION.

At attempt has been made in the time at my disposal to point out what a valuable asset we possess in our veld and yet how little has been done to maintain it or improve it. In considering measures for the protection and more efficient utilisation of the veld, we must first of all accept the fact that it is a national problem and not merely an agricultural problem in which urban dwellers may or may not be interested.

In discussing the main needs of our pastoral policy, namely, more research on pasture problems, more fencing, larger quantities of fertilisers and more machinery, all involving the expenditure of large sums of money, I fully realise that I am laying myself open to a charge of being unpractical or, at best, visionary. When it is considered, however, that in time of war we can tax ourselves to provide many millions for the defence of our country, surely we can plan to spend what would be a much smaller amount to protect and improve one of our most valuable assets. Furthermore, we should try to get a right perspective with regard to the whole field of agriculture, and realise that the first duty of the agricultural section of the population is to feed the rest of the population adequately without bringing about a deterioration of soil and veld.

When this change in outlook has been successfully accomplished, the establishing of the point of view that care of the veld and prevention of erosion are the concern of everyone would be automatic. Here again a great step forward will have been taken when the whole country realises that the prosperity of all in the long run is bound up with the condition of our veld. If the veld is allowed to deteriorate and soil erosion is not checked, the outlook is indeed dark and our future as a nation will be imperilled, for no nation can thrive or progress when its grasslands become eroded deserts or change to impenetrable scrub and its soils become windblown dust.

The programme outlined is an ambitious one, but it is not beyond our capabilities. It calls for careful planning and increased effort, but, if our veld is to play the part it is capable of playing in our agriculture, a programme of this nature is essential. The future of our country is very closely connected with the attitude we adopt towards our veld, which, we may be sure, will always repay in good measure the care and attention devoted to it.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 57-67, November, 1943.*

# HELMINT SPESIFISITEIT

DEUR

DR. R. J. ORTLEPP,

*Onderstepoort.*

*Presidentsrede aan Afdeling D, gelees 28 Junie, 1943.*

---

Die vasstelling van spesifisiteit onder parasitêre diere is nie alleen van groot ekonomiese waarde nie, maar is ook van groot wetenskaplike belang daar dit onder andere tot 'n groot mate kan dien om verwantskappe tussen verskillende groepe diere aan te dui. Dit is bekend dat onder die Mallophaga of bytende luise, wat hoofsaaklik op voëls voorkom, daar 'n sterk spesifisiteit aanwesig is. My oorlede kollega, Bedford—wat 'n deskundige op die groep parasite was—het my dikwels meegedeel dat dit vir hom moontlik was om, alleenlik deur besigtiging van 'n luis, in die meeste gevalle nie alleen die groep waaraan die voëlgasheer behoort vas te stel nie, maar dikwels selfs ook die voëlsoort. Die sienswyse van Bedford word kragdadig ondersteun deur ander luisdeskundiges soos bev. Hopkins van Uganda, Kellog van die Verenigde State en andere.

Waar daar nou so'n eienskap aanwesig is by hierdie parasitêre dieregroep is dit nie alleenlik interessant nie maar ook belangrik indien dit vasgestel kan word, al dan nie, of soiets ook by die parasitêre wurms waar te neem is. So iets is alreeds deur Fuhrmann van Neuchatel beweer met betrekking tot die lintwurms van voëls. Die deskundige, met sy omvattende kennis van lintwurms, gaan so ver as om te beweer dat elke voëlorde sy besondere lintwurmfauna besit, en dat van die duisende voëllintwurms wat hy self ondersoek het hy nog nie één enkele geval teëgekom het wat die reël oortree nie. Waar daar gevalle deur ander werkers gemeld word wat skynbaar nie die reël volg nie, meen hy dat dit òf 'n geval is waar die gashere verkeerd aangegee is, òf die parasite verkeerd geïdentifiseer is, òf dat die parasiet per ongeluk in die sogenaamde gasheer telande gekom het, soos bev. wanneer 'n roofvoël 'n voël eet wat aan 'n ander orde behoort.

Die stelling van Fuhrmann is heftig deur Meggitt van Rangoon bestry, nie soseer met die bewering dat so'n spesifisiteit nie onder die lintwurms voorkom nie maar wel dat dit nie absoluut is nie en dit dus nie as 'n algemene reël aanvaar kan word nie; verder ook op grond daarvan dat daar geen eenstemmigheid onder voëldeskundiges is nie met die gevolg dat dieselfde voëls dikwels deur verskillende deskundiges in verskillende ordes geplaas word. As Fuhrmann se bewering dus reg is dan sal die spesifisiteit van

die lintwurms, volgens die reël, moet varieer al na die klassifikasie van die een of ander voëldeskundige wat gevolg word.

Waar daar dus sulke teenstrydige opvattings bestaan is dit my doel vandag om na te gaan in hoe verre spesifisiteit voorkom nie alleen by die Cestoda of lintwurms nie maar ook by die Trematoda of slakwurms en Nematoda of rondewurms. Dit is nie my doel om elke afsonderlike wurm in oorweging te neem nie maar wel soorte as verteenwoordigende die groot onderverdelings van elke van drie klasse. Die sal, sover moontlik, bestaan uit voorbeelde uit my eie ervaring grotendeels gebaseer op ons Suid-Afrikaanse helminte.

Eerstens die klas Trematoda of slakwurms. Hier wil ek my alleenlik bepaal tot die onderklas Digenea, d.i. die slakwurms wat 'n tussengasheer nodig het in hulle ontwikkeling. Terloops mag egter gesê word dat die meeste soorte van die Monogenea—d.i. slakwurms wat nie 'n tussengasheer nodig het nie vir hulle ontwikkeling—volgens Fuhrmann—alleenlik op een soort gasheer of op nouverwante soorte gashere voorkom. Die vernaamste onderverdelings van die Digenea is die ordes Monostomoidea, Fascioloidea, Paramphistomoidea en Strigeoidea. Die Monostomoidea, wat gekenmerk word deur die afwesigheid van 'n buiksuier, kom hoofsaaklik in reptile en voëls voor, maar party soorte word ook in soogdiere gevind. Hulle het skynbaar geen spesifisiteit wat die soort voël betref nie, maar waar dit voorkom is die spesifisiteit alleen beperk tot die voëlorde, bev. die bekende soort *Typhlocoelium cucumerinum* en *Tracheophilus cymbius* wat in die lugpype voorkom word alleenlik in voëls van die Anseriformes (eendesoort) gevind; maar dit is skynbaar 'n uitsondering want die ander bekende soorte kom dikwels in verskillende voëlordes voor, bev. *Notocotylus attenuatus* en *Catatropis verrucosa* kom beide in Galliformes (hoendersoort) en Anseriformes voor.

Die orde Fascioloidea, lede waarvan gevind word in alle klasse van werweldiere en van groot ekonomiese belang is, bevat sulke welbekende soorte slakwurms soos die lewerslakke; veral dink ons aan ons ou vrinde *Fasciola hepatica* en *F. gigantica*. Die twee soorte kom hoofsaaklik in die hoefdiere voor, maar hulle het hulself nou aan verskillende ander gashere aangepas, want mens kry hulle ook in knaagdiere (konyne), buideldiere (kangaroos), ens., en party kere selfs ook in die mens. Hier sal mens net kan sê dat hulle skynbaar eers slegs by die herkouers voorgekom het, maar dat met die onwillekeurige toedoen van die mens, deur die aanhou van verskillende soorte diere in 'n beperkte omgewing, die parasiet homself geleidelik begin aanpas het by die verskillende huisdiere. Vandag is die toestand so dat al die mens sê soogdiere blootgestel is aan besmetting. Die soort *Fasciola jacksoni* kom vandag nog alleenlik in die Asiatiese olifant voor, maar dit is moontlik dat die parasiet hom ook aan ander diere mag aanpas as omstandighede gunstiger word. Vandag is die kanse hiervoor nie te goed nie want, waar die gashere natuurlik

voorkom of gebruik word, is daar nie die noue samelewing tussen hulle en ander soorte huisdiere wat mens vind by die gashere van eersgenoemde twee soorte nie.

Van die Fascioloidea wat alleenlik in een dierorde voorkom is daar 'n hele paar soorte bekend. Die mees bekende hiervan is *Eurytrema pancreaticum* wat tot dusver alleenlik in herkouers en *Nanophytes salmonicola* wat alleenlik nog in vleisvreters gevind is, ofskoon 'n ander soort van laasgenoemde geslag, nl. *N. schikhobalovi* in die mens in Rusland gevind is. Ander soorte van eersgenoemde geslag is egter wyd versprei en word dikwels ook in voëls en reptile gekry.

Waar bogenoemde paar gevalle aangehaal is van skynbare spesifisiteit onder die Fascioloidea kan daar talle soorte genoem word wat in verskillende gasheerordes voorkom; so bev. het ons die oosterse lewerslak—*Opisthorchis sinensis*—wat gevind word in mense, vleisvreters en varke; die lansetlewerslak—*Dicrocoelium lanceolatum*—wat hoofsaaklik in hoefdiere maar ook in knaagdiere en in die mens kan voorkom; die longslakwurm—*Paragonimus westermanni*—wat gewoonlik 'n parasiet van vleisvreters is, maar ook die mens, knaagdiere en hoefdiere kan besmet.

Die orde Paramphistomoidea omvat die bekende peervormige slakwurms wat so dikwels gevind word in ons skape en beeste. Lede van die orde kom alleenlik in werweldiere voor. Lede van een groep families kom slegs in waterdiere voor, vanaf visse tot soogdiere, terwyl die lede van die orige families alleenlik in land-soogdiere voorkom. Hier is dit skynbaar die omgewing wat vasstel in welke soort dier die parasiet sal voorkom. Dit is nogal opmerklik dat die meeste geslagte voorkom in visse en soogdiere. 'n Betreklike klein aantal geslagte kom in amfibieë en reptile voor, terwyl slegs twee soorte van voëls bekend is. Die spesifisiteit wat die klas gasheer aangaan is nogal taamlik sterk, bev. die lede van die groot onderfamilies Paramphistominae en Gastrothylacinae kom feitlik alleenlik in herkouers voor; die paar uitsonderings is die soorte wat in seekoeie gevind word; maar dit verbaas ons gladnie want die diere is, soos u weet, nou verwant aan die herkouers. Die lede van die Diplodiscinae is tipies vir paddas en is wyd oor die wêreld versprei; hulle kom ook in die nou-verwante salamanders voor en een soort is in 'n waterslang gekry. In Suid-Afrika is daar een soort—*Diplodiscus doyeri*—wat in die platanna leef; dit is die enigste gasheer waarin dit nog gevind is, en die parasiet is in die gasheer gevind in wyd verspreide plekke van die Unie sowel as buite ons grense.

'n Baie interessante dier is die soort bekend as *Brumptia bicaudata* wat veral gekenmerk is deur die aanwesigheid van twee ooragtige aanhangsels aan die agterste gedeelte van die liggaam. Die morfologie van die wurm is so eienaardig dat helmintologe dit goed gevind het om 'n spesiale onderfamilie—Brumptinae—vir hom te skep. Mens sou dink dat so 'n eienaardige parasiet hoogs spesifies sou wees; maar nee, hy kom voor in twee van ons bekendste diere, nl. die olifant en die renoster, twee diere wat,

sover my bekend, nie beskou word as baie na verwant te wees nie; inteendeel, die olifant word gewoonlik beskou as die naaste verwant aan die Sirenia te wees, terwyl die renoster sorteer onder die hoefdiere. Het ons hier 'n geval van 'n parasiet wat hom aangepas het aan twee soorte diere omdat die lewenswyse en fisiologie van die diere miskien baie ooreenstem ofskoon hulle, sover ons weet, nie nou verwant is nie? Ek glo nie dat dit die enigste rede is nie want ander slakwurmsoorte wat behoort aan die geslag *Gastrodiscus* kom ook in die twee gashere voor sowel as in perdesoorte en in vlakvarke; laasgenoemde twee gasheersoorte sowel as die renoster word as na verwant beskou en word gevolglik saam onder die hoefdiere geklassifiseer, ofskoon hulle lewenswyses heelwat verskillend is. Het ons nie hier miskien 'n vingerwysing na 'n moontlike verwantskap tussen die olifant aan die een kant en die renosters, perde en vlakvarke aan die ander, 'n verwantskap wat ons nog nie bespeur het nie? Die enigste paramfistoom wat in die Sirenia nog bekend is is *Chiorchis fabaceus* en die kom in hierdie soogdier alleen voor; as daar enige verwantskap is tussen die Sirenia en die olifante sou mens verwag dat die parasiet, of 'n nouverwante een, ook in die olifant sou voorkom; dit is egter nie die geval nie. Maar, afgesien van verwantskap kan die totaal verskillende lewenswyses van die diere dit heel waarskynlik ook teenwerk.

Soos alreeds gesê kom daar net twee soorte van hierdie slakwurms in voëls voor. Een van hulle—*Zygocotyle lunatum*—is die eerste keer beskrywe van uit 'n herkouer (*Cervus* sp.) en is later weer in 'n bees gekry; nieteenstaande dit kom die soort hoofsaaklik in voëls van die Anseriformes (eendesoorte) voor asook in 'n paar voëls van die Charadriiformes (d.i snippe en strandlopers) en is ook al een keer in 'n hoender gevind. Dit is die enigste geval waar dieselfde soort paramfistoom beide in voëls en in soogdiere voorkom. Daar in die loop van meer as 'n eeu die parasiet nog slegs twee keer in 'n soogdier aangetref is, skyn dit asof mens hier sekerlik nie to doen het met 'n normale soogdierparasiet nie, maar wel met een wat hom heel toevallig in die diere per abuis gevestig het en in hulle fisiologiese omstandighede, wat ons onbekend is, gevind het wat dit vir hom moontlik gemaak het om in die gashere die volwasse stadium te beriek. Nee, ek glo dat ons hier met 'n wurm te doen het wat spesifies is vir die twee voëlordes hierbo genoem—die een geval van sy voorkoms in 'n hoender is heel waarskynlik maar 'n ongeluk en kan dus buite rekening gelaat word—en die rede vir die spesifisiteit is seker nie te vinde in enige nou verwantskap van die twee voëlordes nie maar heel waarskynlik in hulle lewenswyses wat in baie opsigte eenders is.

Die laaste orde van Trematoda wat ek nog wil behandel is die Strigeoidea; die sluit in twee belangrike families—die Strigeidae en die Schistosomidae—lede van laasgenoemde is verantwoordelik vir die welgevreesde bilharziasieke in mens en dier. Die kenmerk van hierdie orde is dat al sy serkarië 'n gesplete stert het saam met 'n ventrale buiksuier.

Onder die Strigeidae tref ons vorms aan wat hoogs spesifies is vir 'n bepaalde dierorde asook soorte wat in verskillende dierordes voorkom. Ons vind bev. dat die geslag *Apatemon* met sy tien bekende soorte alleenlik in Anseriformvoëls voorkom, dat die geslagte *Uvulifer* (4 soorte) en *Pseudodiplostomum* (3 soorte) alleenlik in visvangervoëls (Alcedinidae) gevind word; behalwe een soort van elke geslag kom al die soorte van die geslagte *Apharyngostrigea* en *Posthodiplostomum* in reiervoëls (Ardeiformes) voor. Al die lede van die geslag *Alaria* word in soogdiere gevind, 11 soorte in vleisvreters, en een in 'n knaagdier, en al die lede van die familie Proterodiplostomidae kom slegs in reptile voor. Aan die ander kant kan ons die geslagte *Strigea*, *Cotylurus* en *Neodiplostomum* stel. Die geslag *Strigea*, waarvan 19 soorte bekend is, is al in 12 voëlordes gevind, en ofskoon hulle so wyd versprei is besit party soorte nogal 'n sterk spesifisiteit; bev. die soort *S. falconis* kom, met uitsondering van twee twyfelagtige gevalle, slegs in roofvoëls voor, en die soort *S. strigis* word, met uitsondering van twee twyfelagtige gevalle, alleenlik in uilsoorte gekry. Daarenteen kom *S. bulbosa* in 4 voëlsoorte voor versprei onder 3 voëlordes, nl. Caprimulgiformes (nagvalkies) Ardeiformes (reiersoorte) en Accipitriformes (roofvoëls). Lede van die geslag *Cotylurus* (10 soorte) is in 11 voëlordes gevind, maar enkele van hulle is baie spesifies, bev. *C. flabelliformis* kom in die natuur slegs in Anseriformes voor; daarenteen kom *C. platycephalus* in 15 voëlsoorte voor, versprei onder 6 voëlordes, en *C. cornutus* in 12 voëlsoorte versprei onder 2 voëlordes. Die geslag *Neodiplostomum* met sy 29 bekende soorte is wyd versprei; 15 soorte kom uitsluitlik in roofvoëls voor en die orige soorte is onder 6 verskillende voëlordes versprei waar die soorte egter spesifies is vir die voëlorde waarin hulle voorkom.

Die Schistosomidae is egte bewoners van die bloedvate en is gekenmerk deur die feit dat die geslagte van mekaar geskei is. Hulle word in voëls en soogdiere aangetref waar hulle geweldige steurings veroorsaak wat kan lei tot die dood van die aangetaste dier. In Suid-Afrika het ons twee soorte, nl. *Schistosoma haematobium* wat in die mens voorkom en *S. bovis*, 'n parasiet van hoefdiere. Wat veral treffend is van die twee soorte is dat, behalwe die vorm van die eiers, hulle morfologies en biologies identies is; nogtans is hulle in die natuur spesifies elk vir sy eie soort gasheer. Behalwe vir een geval in 'n bobbejaan is *S. haematobium* nog slegs in die mens gevind en *S. bovis* is met sekerheid nog nooit in die mens gekry nie; waar laasgenoemde van die mens gerapporteer is is die bevinding alleenlik gebaseer op eiers wat soos die van *S. bovis* gelyk het; hierop kan mens egter nie 'n definitiewe vasstelling maak nie, want dit is bekend dat in abnormale gevalle een en dieselfde wurms eiers kon afskei wat varieer vanaf die tipiese *S. haematobium* eier tot die tipiese *S. bovis* eier. Ook is dit bekend dat daar wêrelddele is waar *S. bovis* volop in diere voorkom maar geen gevalle van bilharzia besmetting onder die mense vasgestel is nie, wat nie die geval sou gewees het as die soort nie spesifies vir sy soort gasheer was nie.

Die oosterse vorm van bilharziawurm—*S. japonicum*—kan genoem word as 'n voorbeeld van die ander uiterste; hier het ons 'n wurm wat wêreldberug geword het deur die slagoffers wat hy onder die oosterse mense geverg het; en nogtans skyn dit nie of die mens sy natuurlike gasheer is nie, want die wurm kom natuurlik in verskillende hoefdiere voor sowel as in honde en katte; hulle nadelige effekte op die diere is nie so geweldig as in die mens nie. Het ons hier nie miskien 'n geval van 'n wurm wat besig is om homself by die mens aan te pas nie? Ons weet dit is tot voordeel van 'n parasiet om sy gasheer so min moontlik te beskadig om daardeur sy eie lewensbestaan te beveilig, maar dat by die mens die aanpassing van die parasiet by sy gasheer nog nie sover gevorder het om die nodige harmonieuse samelewing van parasiet en gasheer te bewerkstellig nie.

Wat die ander lede van die Schistosomidae aangaan wil ek slegs nog dit byvoeg; waar lede van die onderfamilie Schistosominae beide in soogdiere en voëls voorkom, word die lede van die ander onderfamilie—Bilharziellinae—alleenlik in voëls gevind, en, met uitsondering van 'n paar soorte, alleenlik in voëls van die eendeorde.

Dit, dames en here, is 'n kort oorsig van die stand van sake wat die slakwurms aangaan. Voorbeelde is genoem van slakwurms wat skynbaar hoogs spesifies is vir hulle bepaalde gasheer, ander weer wat spesifies is alleelik vir 'n groep gashere wat nou-verwant aan mekaar is, terwyl ander weer skynbaar geen spesifisiteit toon nie. Wat is nou die algemene indruk oor die spesifisiteit wat mens by so 'n oënskou opdoen? Ek glo mens kan dit saamvat in die volgende woorde:—Daar is duidelike bewyse dat spesifisiteit onder die slakwurms aanwesig is, maar dit is in die meeste gevalle beperk tot 'n nou-verwante groep diere en nie soseer tot 'n besondere soort gasheer nie.

Ek gaan nou oor tot die tweede klas van parasitêre wurms, nl. die Cestoidea. Die word in twee onderklasse verdeel, nl. die Cestodaria en die Cestoda. Eersgenoemde onderklas bevat slegs 'n klein aantal geslagte en hulle soorte is in die meeste gevalle hoogs spesifies vir een of ander klas gasheer, bev. die geslag *Amphilina* word alleenlik gevind in visse van die *Acipenser* soort, terwyl die geslagte *Gyrocotyle* en *Gyrocotyloides* alleenlik in *Chimeria* en *Callorhynchus* gevind word, d.i. hulle is beperk tot die Holocephali visse. Die geslag *Gephyrolina* is tot sover alleenlik in Siluroid (barbelsoorte) visse van Indië gevind.

Die onderklas Cestoda omhels die allergrootste deel van die lintwurms en word in vyf ordes verdeel. Twee van hulle—die Diphyllidea en Tetrarhynchidea—is beperk tot die selachii (haaisoorte) visse, die derde orde—Tetraphyllidea—word in visse, amfibië en reptile gekry, terwyl die orige twee ordes Pseudophyllidea in alle werweldierklasse en Cyclophyllidea hoofsaaklik in voëls en soogdiere, maar partykere ook in amfibië en reptile gevind word.

Een van die families van die Tetraphyllidea is die Proteocephalidae; lede hiervan is baie spesifies want hulle bewoon óf

een soort gasheer òf hulle word in na-verwante gashere gevind, bev. die lede van die geslag *Acanthotaenia* is tipies van likkewane en behalwe een soort—*A. gallardi*—word hulle in geen ander dier gevind nie. Wat. *A. gallardi* betref het ons hier te doen met 'n interessante geval waar 'n likkewaanlintwurm hom skynbaar by slange aangepas het; die parasiet kom in Australië voor waar daar geen egte slanglintwurms voorkom nie, en om die gebrek aan te suiwer is daar na die likkewane gegaan. Die geslag *Ophiotaenia* word deur party helmintologe in twee geslagte verdeel, nl. *Ophiotaenia* (s.s.) wat sy verteenwoordigers alleenlik in slange vind, en die geslag *Batrachotaenia* wat bestaan uit lintwurms afkomstig van paddas en salamanders. Die orige ses families van die Tetraphyllidea is nie so spesifies as wat lede van bogenoemde familie is nie, bev. vyf van die families het hulle verteenwoordigers alleenlik by die selagiers of haaie en die orige familie bestaan uit lintwurms afkomstig van die siluroide of barbelagtige visse.

Die orde Tetrarhynchidea is 'n orde van eienaardige lint wurms wat met een uitsondering--in die ganoid, *Amia*—alleenlik in Selachiers voorkom. Die kenmerkende eienskap van die groep is dat al sy lede voorsien is van vier uitstulpbare en met 'n menigte hake bewapende slurpe. In ons land vind ons dikwels die jong of larfstadium in stokvis en kaapse salm wat te koop aangebied word; gelukkig egter, is hulle vir die mens onskadelik, en, behalwe van 'n estetiese oogpunt, is die vleis van sulke besmette visse heeltemal geskik vir menslike gebruik.

Die orde Pseudophyllidea word gewoonlik in sewe families verdeel wat meer as 50 geslagte bevat; lede van 6 van die families kom uitsluitlik in waterdiere voor, hoofsaaklik in visse maar ook in waterskildpaaie waarin verteenwoordigers van een van hierde ses families voorkom. Die sewende familie—Diphyllobothriidae —word verteenwoordig deur lintwurms afkomstig van amfibië, reptile en soogdiere. 'n Bekende soort is *Ligula intestinalis* wat in ons land asook in ander wêrelddele voorkom; die larfstadium kom in verskillende visse voor en die volwasse stadium in verskillende watervoëls wat onder 'n half dosyn of meer voëlordes sorteer. 'n Ander bekende soort is *Diphyllobothrium latum*, die breë lintwurm van die mens, wat gelukkig nie in Suid-Afrika voorkom nie maar wel in Noord Amerika, Europa en die Ooste; die wurm kom ook dikwels voor in honde en katte en ander vleisvretende diere. *D. erinacei* is 'n nou-verwante soort wat wyd versprei is, ook in Suid-Afrika, en in vleisvretende diere voorkom, en daar is 'n moontlikheid dat dit die mens ook kan parasiteer. Wat hierbo gesê is sal genoeg wees om aan te toon dat daar by die orde van lintwurms nie 'n spesifisiteit is nie wat die soort gasheer aangaan, maar dat die voorkoms van die wurms alleenlik beperk is tot diere wat visse eet, wat wel te verstaan is, daar die larfstadium van hierde lintwurms in visse voorkom.

Die orde Cyclophyllidea omhels die grootste aantal van bekende lintwurms waaronder ook die bekendste soorte; hulle

word hoofsaaklik in voëls en soogdiere gevind maar 'n paar soorte kom ook in amfibië en reptile voor. Die geslag *Taenia* is veral bekend deur die twee soorte *Taenia solium* en *T. saginata* wat in die mens voorkom en, tot dusver, in hulle volwasse stadia nog in geen ander gasheer gekry is nie. Hier het ons te doen met twee lintwurms wat in hulle volwasse stadia hoogs spesifies is vir een bepaalde soort gasheer; in hulle larfstadia is hulle ook taamlik spesifies want dié kom hoofsaaklik in varke en beeste onderskeidelik voor, ofskoon die stadia by uitsondering ook in ander diere kan voorkom. Die soort *Echinococcus granulosus* (=*Taenia echinacoccus*) vind sy normale gasheer in honde, en ofskoon dit tot 'n seker mate in katte kan ontwikkel, is dit gevind dat die parasiet nie in katte geslagsryp kan word nie; 'n na-verwante soort wat in leeus gevind is is *E. felidis* (=*T. felidis*) wat heel waarskynlik ook in ander katte 'n normale ontwikkeling sal deurmaak. In teenstelling met bogenoemde twee *Taenia* soort wat spesifies is vir die mens, vind ons dus dat die twee *Echinococcus* soorte alleen spesifies is vir 'n bepaalde klas van dier, nl. die soort *granulosus* vir vleisvreters van die honde soort, en die soort *felidis* vir vleisvreters van die katte klas.

Wat die ander geslagte van die familie Taenidae aangaan kan mens sê dat hulle sterk aanduiding van spesifisiteit aantoon, veral wat die klas dier aangaan; slegs een geslag nl. *Taenia*, kom beide in soogdiere en voëls voor, maar in laasgenoemde diere is hulle voorkoms 'n rariteit want die beskrewe soorte wat in voëls voorkom is elk, sover my bekend, nog maar slegs een keer gevind. Slegs een geslag—*Cladotaenia*—met sy paar soorte kom alleenlik in roofvoëls voor terwyl al die ander geslagte beperk is tot die soogdiere.

Terwyl die lede van die familie Taeniidae in hoofsaak karakteristiek is van soogdiere vind ons dat die lede van al die orige families, met uitsondering van die families Anoplocephalidae en Nematotaeniidae, hoofsaaklik in voëls voorkom waar hulle verteenwoordigers onder die ganse voëlryk versprei is; die verskillende soorte, egter, is spesifies vir 'n bepaalde soort of klas van voël. As ons bev. ons korane neem dan vind ons dat hulle gekenmerk is deur die aanwesigheid van sekere soorte van die geslagte *Chapmania*, *Idiogenes*, *Schistometra*, *Sphyronchotaenia*, ens., welke soorte nog nie in 'n ander klas van voël gevind is nie. Of neem die tarentale; hulle behoort aan dieselfde orde as die hoender, en mens sou dink dat dieselfde soorte lintwurms in beide sou voorkom. Maar my ondervinding is dat dit in die natuurlike staat nie die geval is nie; die soorte van die geslag *Octopetalum* bev. wat baie in ons tarentale gevind word is nog nooit in hoenders of na-verwante voëls gevind nie. Hoe spesifies die lintwurms is word veral deur die soort *Houttuynia struthionis* bewys wat die enigste soort lintwurm is wat in ons struisvoëls voorkom, en alleenlik in die voël in ons land gevind is. In Suid-Amerika, soos u weet, leef die na-verwante rhea, en wonderbaarlik leef 'n varieteit van dieselfde soort lintwurm ook in die voël,

nieteenstaande die feit dat Afrika en Amerika duisende myle van mekaar af lê en hulle van mekaar geskei is vanaf díe duistere verlede. Het ons hier 'n geval van parallelle evolusie of is dit 'n geval waar 'n lintwurm van 'n gemeensame oertiepe van die voëls in sy hedendaagse verteenwoordigers bly voortbestaan het? Ons weet nie. Al wat ons kan sê is dat die nouverwantskap van die twee voëls, wat op morfologiese gronde gebaseer is, kragdadig deur die aanwesigheid van feitlik dieselfde parasiet ondersteun word.

So kan mens aangaan met voorbeelde noem, maar ek glo dat bogenoemde voorbeelde u 'n insage sal gee wat die toedrag van sake is met die lintwurms. Eer ek egter van hulle afstap wens ek net te beklemtoon dat in die lintwurms ons nie moet verwag dat die geslagte spesifies sal wees vir een of ander soort of klas van gasheer nie, ofskoon dit dikwels die geval mag wees, maar wel dat die soorte in hulle verspreiding beperk bly tot na-verwante diere. Waar dit skynbaar nie so is nie soos in die geval van *Hymenolepis nana* van muise en rotte en die mens, of *Dipylidium canium* van die hond en die kat en wat ook in die mens kan voorkom, het ons in eersgenoemde parasiet moontlik 'n geval van biologiese varieteite wat morfologies skynbaar identies is, of ons het te doen met werklik een en dieselfde soort wat homself in die loop van tyd aangepas het aan albei klasse gashere; so'n buitengewone aanpassing van die wurm behoort ons nie te verras nie want in 'n ander opsig is hy ook eienaardig, nl. daarin dat hy nie alleen 'n indirekte lewensloop volg, soos ander ordentlike lintwurms, waar 'n insek of ander dier as tussengasheer dien nie, maar hy besit ook die sonderlinge vermoë om self sy finale gasheer as tussengasheer te gebruik, en op die manier 'n intensifisering van sy besmetting te bewerkstellig. *Dipylidium caninum*, aan die ander kant, wat tipies 'n parasiet van vleisvreters is, vind in die mens omstandighede vir ons onbekend wat gunstig is vir sy ontwikkeling nieteenstaande die feit dat vleisvreters en die mens nie nou-verwante diere is nie. Maar die lewe is vloeibaar en sulke uitsonderings moet ons verwag; dit is soos 'n stroom water wat kort-kort van koers verander in sy pogings om sy uiteindelike bestemming, die see, te bereik.

Ons kom nou tot ons laaste klas van parasitêre wurms, nl. die Nematoda of rondewurms. Dit is 'n baie groot klas waarvan alreeds meer as 3,000 soorte bekend is wat versprei is onder alle soorte werweldiere, om nie eers te praat van die talryke soorte wat in die laer diere of in die vrye natuur voorkom nie. Deur die belangrike ekonomiese rol wat hulle speel en die feit dat baie soorte in ons huisdiere voorkom is die klas as 'n geheel baie beter bekend as die slakwurms of die lintwurms. Ek voel my verplig om my aandag te beperk tot slegs 'n klein aantal soorte van hierdie wurms, maar ek vertrou dat die voorbeelde wat behandel sal word genoegsaam sal wees om u 'n insig te gee in hoe verre spesifisiteit in die klas parasite waar te neem is of nie.

Die klas word in vyf ordes—party kere ook superfamilies

genoem—verdeel, nl. die Ascaroidea, Strongyloidea, Filaroidea, Dioctophymoidea en Trichiuroidea.

Aan die Ascaroidea behoort sulke welbekende wurms soos die elswurm—*Ascaris lumbricoides*—en die naaldwurm—*Enterobius vermicularis*—wat albei in die mens voorkom; eersgenoemde—of liewer 'n biologiese varieteit daarvan—kom ook in die vark voor, terwyl laasgenoemde uitsluitlik 'n menslike parasiet is. In die orde vind ons baie soorte wat spesifies is vir 'n seker soort of klas van dier, bev. *Ascaris vitulorum* en die soorte van die geslag *Skrjabinema* is beperk tot herkouers, *Ascaris equorum* en *Oxyuris equi* tot die perdesoorte, die soorte van die geslag *Passalurus* tot knaagdiere met *P. ambiguus* alleenlik in hase en konyne. Die soorte van die geslagte *Ascaridia* en *Heterakis*, wat hoofsaaklik in voëls voorkom, word ook in ander diere gevind. *A. columbae* kom alleenlik in duiwesoorte (Columbiformes) voor, en *H. dispar* word alleenlik in eendesoorte (Anseriformes) gevind; aan die ander kant kom die soorte *A. lineata*, *A. galli* en *H. gallinae* beide in hoendersoorte en in eendesoorte voor. Die soorte van die geslagte *Porrocaecum* en *Contracaecum* word alleenlik in visvreters gekry, wat òf soogdiere, òf voëls òf visse kan wees.

Onder die Strongyloidea vind ons geslagte wat baie tipies is vir 'n seker soort dier of diergroep: In die opsig is die vorms wat in die perdesoorte (Equidae) voorkom nogal baie treffend, bev. die meer as 50 soorte van die geslag *Trichonema*, die 4 soorte van die geslag *Triodontophorus*, 4 van die 5 soorte van die geslag *Strongylus* ens. kom alleenlik in die diere voor, terwyl die 5 soorte van die geslag *Cylindropharynx* nog meer spesifies is want hulle is beperk tot die Sebras. Die olifante dra ook 'n baie karakteristieke fauna wat hulle tot 'n seker mate ook deel met die renosters, ofskoon die afsonderlike soorte beperk is tot die een of die ander van die diere. Die haakwurms van die geslag *Bunostomum* kom alleenlik in herkouers voor, met die soort *B. trigonocephalum* in skape en bokke en die soort *B. phlebotomum* in beeste. Aan die ander kant vind ons dat die menslike haakwurms—*Ancylostoma duodenale* en *Necator americanus*—ook in vleisvreters en varke kan voorkom. Die verskillende soorte haarwurms (*Haemonchus* soorte) is karakteristiek van hoefdiere en word hoofsaaklik in herkouers gevind, maar die soort *H. contortus* kan ook in ander diere voorkom en is al in mense, bere en eekhoorns gevind; dit is nogal opmerklik dat die soort nog nie sy verskyning in die perd gemaak het nie ofskoon die dier gewoonlik saam met beeste, skape en bokke op dieselfde weiveld loop en dus gedurig aan besmetting blootgestel is; maar aan die ander kant vind ons weer dat die karakteristieke helmint fauna van die perd ook nie in skape, bokke of beeste voorkom nie. Soorte van die geslag *Dictyocaulus*—die longwurms—kom egter in al die diere voor maar elke soort is spesifies vir sy gasheer, nl *D. filaria* vir skape en bokke, *D. viviparus* vir beeste en *D. arnfieldi* vir perde.

Die Dioctophymoidea omhels slegs 'n klein aantal soorte wurms wat aan 4 geslagte behoort. Die vernaamste wurm onder

hulle is *Dioctophyme renale* wat feitlik slegs in vleisvreters voorkom, maar by uitsondering ook in ander diere gevind work asook in die mens. Die ander soorte word òf in vleisvreters òf in voëls van die eendesoorte gevind.

Onder die Filaroidea tel ons 'n menigte soorte van alle groottes en vorm; die filarias.van die mens is aan u almal bekend. Dit is treffend hoe spesifies baie van die wurms is, bev. die soorte *Wuchereria bancrofti*, *Loa loa*, *Onchocerca volvulus* en *Mansonella ozzardi* parasiteer alleenlik die mens; *Onchocerca cervicalis*, *O. reticulata* en die *Habronema* soorte *muscae*, *microstoma*, *megastoma* en *zebrae* alleen die perdesoorte; soorte van die geslag *Litomosa* alleen die vlêrmuise; *Dirofilaria immitis*, *Spirocerca lupi* en *Physaloptera praeputialis* alleen die vleisvreters. Aan die ander kant vind ons dat 'n ander menslike parasiet—*Dracunculus medinensis*—ook in honde en ander vleisvreters sowel as in perde, beeste en skape kan leef, d.i. in 'n verskeidenheid van groepe soogdiere wat nie na verwant aan mekaar is nie. Dan is daar ook geslagte waarvan die soorte in verskillende dierordes versprei is, soos bev. die soorte van die geslag *Physaloptera* wat in soogdiere, voëls en reptile voorkom maar die afsonderlike soorte, egter, baie spesifies is vir die diergroep of soort waarin hulle voorkom; dieselfde geld ook vir die soorte van die geslagte *Habronema*, *Gongylonema* en *Thelazia* van soogdiere en voëls, en *Spirura* van vleisvreters en die rhea.

Onder die Trichiuroidea vind ons 'n wurm wat in die mens en feitlik in alle soogdiere kan voorkom; dit is die spierwurm *Trichinella spiralis* wat ook al aan voëls oorgedra is; weëns sy wye verspreiding is die mens gedurig aan die gevaar van besmetting blootgestel; gelukkig, egter, het die parasiet nog nie sy verskyning in ons land gemaak nie. 'n Ander menslike wurm is die sambokwurm—*Trichuris trichiura* wat normaallik verwante diere asook varke as gashere het. Ander soorte van die geslag is spesifies òf vir vleisvreters òf knaagdiere òf herkouers. Van die *Capillaria* soorte vind ons dat hulle in hoofsaak òf in voëls òf in vleisvreters voorkom onder welke diere hulle baie spesifies is. Die enigste soort wat van hierdie reël afwyk is *C. hepatica* wat nie alleenlik in sy normale gashere (knaagdiere) voorkom nie maar ook die mens en die hond kan parasiteer.

Dames en Here, met bostaande het ek probeer om u 'n beknopte oorsig te gee van die verspreiding van die parasitêre wurms in die diereryk; ofskoon ek in die beperkte tyd tot my beskikking verplig was om u aandag te bepaal tot slegs 'n klein aantal soorte, glo ek dat die voorbeelde, en wat oor hulle gesê is, voldoende sal wees om u te oortuig dat spesifisiteit tot 'n baie groot mate 'n kenmerk is van die groep diere. Waar die spesifisiteit in baie gevalle nie absoluut is nie moet die feit ons nie teleurstel nie, want ons het hier met lewende organismes te doen in wie daar 'n gedurige stryd aan die gang is om hulle voortbestaan te verseker; om die doel te bereik is dit vir hulle verpligtend om hulleself aan te pas aan soveel gashere as moontlik.

South African Journal of Science, *Vol. XL, pp. 68-80, November, 1943.*

# SOUTH AFRICA'S PART IN THE SOLUTION OF THE PROBLEM OF THE ORIGIN OF MAN

BY

Dr. R. Broom,

*Transvaal Museum, Pretoria.*

*With 2 Text-figures.*

*Presidential Address to Section E, read 28th June, 1943.*

Though South Africa is far from the centre ot the world, and is not likely to have been the centre in which man evolved, its geographical situation has led to its being a very important centre from the anthropological point of view. During the last million years it has been little affected by the great changes in climate experienced by the Northern Hemisphere. It has been a sort of harbour of refuge to which a considerable variety of northern types emigrated, and where they lived for probably long periods; and where remains of them are not infrequently found; and it thus has become almost a museum of early and interesting types.

The Sahara almost completely divides the north of Africa from the Equatorial region and South Africa, and for very long periods it must have been a nearly impassable barrier. In the south the Kalahari must also, for perhaps the greater part of the Pleistocene, have been a substantial barrier passing half way across the continent. Few immigrations are thus likely to have taken place into South Africa, except by the Nile Valley and the east coast. Further, the western half of South Africa, during most of the human period, must have had a very small rainfall and been a relatively inhospitable land; and human races that did manage to reach South Africa must have been little molested for long periods by the races that had settled in the more fertile east coast farther north.

Until near the end of the last century the study of man and his origin had been entirely confined to European specimens. Then in 1891, Dr. Dubois discovered the famous apeman of Java—*Pithecanthropus erectus*—and since then other specimens have been found, and the remains of perhaps two or possibly three other human races in Java. In 1930 the world had revealed to it a wonderful new type of skull, the Pekin man, allied to Pithecanthropus, but much more definitely human and much better preserved.

The study of these Asiatic types and of the European Neanderthals and Piltdowns, and of the Heidelberg jaw, has led to many differences of opinion as to how modern man is related to these early types, and from which, if from any of them, he has evolved. The question is an extremely important one, and it seems improbable that it can be settled even now, with the much further evidence that is available.

Australia has given to the world a number of very interesting early human skulls, all apparently allied to some of the living types, but showing reason to believe that the Australian type of man is very old. America has not yielded us much new light on the origin of man; but the Punin skull of Ecuador seems to show that an Australoid type of man lived in America perhaps even as early as the Middle Pleistocene.

South Africa has given us quite a number of types of early man, mostly differing considerably from those of Europe and Asia; and East Africa has given us the remains of two other early types of man; though, unfortunately, these remains are not in very good condition, and some European scientists have doubts of their being as old as they are said to be. Still Central and South Africa have revealed types of man that must be considered in any discussion of his origin and antiquity; and the South African evidence may lead to some alteration in the opinions of most European scientists.

Apart from the Kafir tribes who have come into South Africa from the north in the historical period, we have, in my opinion, certainly three, and probably four, South African races of man already known. All the early explorers speak of two races, the Bushmen and the Hottentots, and these have generally been regarded by all laymen as very distinct. But, unfortunately, a number of scientists have maintained that they are merely varieties of one race.

Shrubsall, who made a very full study of Bushman skulls, and then of Hottentot skulls, came to the conclusion that the Bushman was a very distinct race, but that the Hottentots were the descendants of an early cross between Bush and Bantu. Then later, Keith held that Bush and Hottentot are really varieties of the same race. No doubt some European scientists were misled by having had sent to them skulls of Hottentots which were labelled "Bush," and Shrubsall was also in part misled by the fact that Kafirs from Pondoland have skulls that are often not unlike those of Hottentots. The reason for this is that the Kafir tribes that invaded Pondoland killed off the Hottentot men, but kept the women. Even to-day many of the old Kafirs will tell you that their grandmothers were Hottentots.

When I went to live at Douglas, in 1917, I became interested in the Bushman-Hottentot problem. Bushmen, if at all pure, can always be easily recognised anywhere; and there were a number of Bushmen living in and around Douglas. There were

also considerable numbers of another race that might be called Hottentots, but many differed considerably from what were called Hottentots in the Western Cape Colony. This other race called themselves Koranas. They are a moderate sized race with rather broad noses, considerably darker than the Cape Colony Hottentots, and with long very narrow skulls.

I made large collections of skulls of both Bushmen and Koranas from graves; and though for a time one could not be certain of the races of the skulls from these old graves, the uncertainty was overcome by getting the skulls of both a pure Korana and a Bushman who had died in gaol. Among the Koranas, of whom there are still considerable numbers in the Herbert and Kimberley districts, I found what seemed to be evidence of two races intermixed. Besides the typical Koranas with narrow skulls and rounded and sloping foreheads, some have broad brows with well marked supraorbital ridges. These latter I regarded as evidence of an earlier Australoid race, and I called them Australoid Koranas.

The majority of anthropologists remained unconvinced, and held that all the yellow skinned races are really varieties of the Bushman. Then Dr. Pyper began studying the blood groups of those Bushmen and Hottentots that he could come across, and he made a very interesting discovery. He found that relatively pure Bushmen have blood of O and A groups with relatively little B, while the Hottentots, even though not very pure, have blood that has mainly O and B. And he holds that the pure Bushman must have been an O and A race, while the pure Hottentot must have had a larger percentage of B than any other race at present known. He thus confirmed the views I had come to from the study of the skulls, that the Bushman and the "Hottentot" were originally two very distinct races. Of course the Bushmen and the "Hottentots" have frequently mixed, and all intermixtures can be met with.

If I am right in considering that we have two main yellow skinned races, it seems better to call them Bushman and Korana, and to retain the name Hottentot for what is almost certainly the Bush-Korana mixture. These Hottentots are to-day mainly found in the western half of Cape Colony and Namaqualand. We have the fairly pure Koranas in the western side of the Orange Free State, and a few in the Eastern Cape Colony, where they were called Gonaquas.

Of early human skulls we have at least six in South Africa. These are the Rhodesian skull, the Springbok Flats skull, the Boskop skull, the Cape Flats skull, the Fish Hoek skull, and the Florisbad skull. A good many other skulls are known, and some are of fair antiquity, but they are of secondary importance.

The Rhodesian skull is by far the most important early human skull found in South Africa. It was obtained from a cave in Northern Rhodesia in 1924. Unfortunately, the accounts of how it was found differ greatly. One says the whole skeleton

was there; another that there was only the skull. The skull was sent to the British Museum with a number of human bones; but when the bones were examined it was found that they belonged to at least three individuals, and probably none of them belong to the skull. The bones seem to be all bones of *Homo sapiens*, while the skull is certainly that of a primitive type of man which differs very greatly from modern men.

It seems possible that the skull comes from an older deposit than that in which it was found, owing to the materials in the hill having been disturbed by some earth movement. We have now no way of determining the age of the skull, as no scientific examination was made of the deposit at the time. One fossil species of Leptaelurus has been described, but the other remains found are apparently of living species; and possibly none of them were contemporaneous with the Rhodesian skull. Not improbably the skull may be of Middle Pleistocene age; it may possibly be even earlier.

The skull is remarkable for the huge size of the supraorbital ridges, the great length of the face and for the absence of a canine fossa. In the first and third of these characters it agrees considerably with the Neanderthal skulls, but in the second character it differs markedly. It also differs in the teeth. While in Neanderthal man the teeth agree rather closely in their crown structure with those of *Homo sapiens*, the Rhodesian teeth differ considerably.

Smith Woodward, who first described the skull, made it the type of a new human species, and called it *Homo rhodesiensis*. He and most other writers have regarded it as being allied to the Neanderthals, mainly by reason of its great supraorbital ridges. But the face is very unlike, and the brow is not at all Neanderthaloid. Having only the one skull, without the mandible, it is hardly possible to determine with any certainty the affinities of this remarkable type. Possibly it will prove to be an aberrant development from a type like the Ngandong man from Java. Unfortunately, we do not know the face of this type.

The Boskop skull is only known by the top of the calvaria with a good temporal bone, part of a mandible and a few fragments of little importance. It was found in a superfiicial lateritic deposit at Boskop, near Potchefstroom, in 1913. We cannot determine the age. The skull is completely fossilised. From one implement found in association, it seems to belong to the Middle Stone Age. It may quite well be 10,000 years or 50,000 years old.

The skull is unlike any other known. It is one of the largest ever found. It measures in length 212 mm., and in greatest width at least 153 mm. The bone in places is thick and in other places relatively thin. There are no large supraorbital ridges. The brow, though prominent, is very narrow,

and the parietal eminences well marked. The brain must have been very large. Possibly it was over 1,800 cc.

The skull is not in the least Neanderthaloid, but though it is so very large it has a number of characters which we find in typical Bush skulls. Possibly it may be near to the ancestral undegenerate Bushmen. Though the living Bushmen are usually dwarfed, and with small brains, some Bush skulls from caves have very large brains, as we see in the Plattenberg Bay skull, described by Drennan. But until we find other examples of Boskop man, we must also leave his affinities as uncertain.

The Springbok Flats skull is, fortunately, fairly well preserved, and we have a good deal of the skeleton. Like the Boskop skull, it was found in a superficial deposit of what we call surface limestone. It is completely fossilised. It must be fairly old, but we have no way of determining the age. Like the Boskop skull, it may be 10,000 years or 50,000 years old, or even much more. It was found with remains of the extinct giant buffalo *Bubalus baini*, and an extinct large horse, probably *Equus capensis*.

The skull and skeleton belong to a large powerfully built man, and a typical *Homo sapiens*. The brain is a little larger than that of most Europeans of to-day, with a well developed brow, but with no trace of Neanderthaloid supraorbital ridges.

Again, having only one skull, it is rather risky to decide on the race. It does seem probable, however, that he is an early Korana or an allied type.

The Fish Hoek skull and skeleton are well preserved, but probably not of very great antiquity. Quite probably they are only a few thousands of years old. The skull is held by Keith and others to be an early Bush type. But while it may have a little Bush blood it is clearly not what I would consider a Bush skull, while it resembles, in most of its characters, skulls that are definitely Korana. Most probably it is a Korana skull with a little Bush admixture.

The Cape Flats skull and the Florisbad skull are of a somewhat different type from those of most Koranas. The Cape Flats skull, while probably of no very great antiquity, is an Australoid skull, very unlike that of the Bushman, but agreeing fairly closely with what I have called the Australoid Korana.

The Florisbad skull is a very remarkable one. It is of considerable antiquity, being associated with a number of extinct mammals, and is probably of Upper Pleistocene Age. With it were found many implements of Middle Stone Age. We might provisionally put it at between 50,000 years and 100,000 years old.

The skull is imperfect, consisting only of much of the face, the frontals and much of the parietals. The brow is very broad and slopes backwards, and it has moderately well developed supraorbital ridges. Had the brow alone been found many would have considered that it is a form of Neanderthal, but

the face is quite unlike the Neanderthal type, having remarkably well developed canine fossae. The skull bears a distinct resemblance to the Wadjak skulls of Java, and we may regard it as an early African Australoid type which once lived at the Cape, perhaps before the Bushman and the Koranas.

The evidence is too slight to enable us to decide whether the Florisbad type is related to the Rhodesian skull. Though the flattened brow with the considerable supraorbital ridges support a possible affinity, the face is very different, and the probability seems to be rather in favour of the Florisbad belonging to a distinct race.

The consideration of these South African skulls raises two interersting and much discussed problems; whether the Neanderthal race is ancestral to *Homo sapiens* and whether *Homo sapiens* is a very old type—perhaps even older than Neanderthal man, and perhaps even ancestral to it.

When, before 1890, Neanderthal man was the only human race known that differed from *Homo sapiens* it was natural for those who were on the outlook for missing links to assume as not improbable that the Neanderthal race was an ancestral human type. The large supraorbital ridges were compared to those of the gorilla, and the absence or slight development of the chin was also considered to be an anthropoid character. Even those who could not agree to the Neanderthal man being an ancestor considered that this race was a survival of a very early type of man who retained a number of simian characters.

Then the discovery of Pithecanthropus, in 1891, seemed to give further support to the view that man had come from a type somewhat like Neanderthal man. In Pithecanthropus we had a primitive man with a small brain and with a flat brow and very marked if small supraorbital ridges. Then forty years later Sinanthropus skulls were found, which showed that early man undoubtedly had a small brain and supraorbital ridges and a rounded chin.

In 1929 the eminent American anthropologist Hrdlicka revived the theory that Neanderthal man was the ancestor of *Homo sapiens*; and ten years later Coon, in discussing the Mount Carmel skulls, gave his support to the same view. He says: "Keith and McCown have demonstrated beyond serious doubt that the skull and skeletons are intermediate between *Homo neanderthalensis* and *Homo sapiens*, and that Neanderthal must, therefore, be included among the ancestors of modern races."

At Mount Carmel there have been found in caves a number of good skulls, some of which are pretty manifestly a variety of *Homo sapiens*—Australoid skulls with small but very distinct supraorbital ridges, and with them at least one skull, that of a woman, who is manifestly a Neanderthal type. This latter skull has been called the Tabun skull. If we assume, as do Keith and McCown and some others, that this Mount Carmel

people represent one race, then we see at least one member apparently a Neanderthal type and the other resembling modern man, except for the distinct supraorbital ridges, and the natural conclusion would be to regard the Mount Carmel tribe as one that is evolving from a Neanderthal type to a *Homo sapiens* type.

But surely a far more natural explanation would be to conclude that we had then living in Palestine two very distinct races—one a powerfully built race essentially *Homo sapiens*, and the other a Neanderthal race; and that while the more virile race probably attacked and killed off many of the Neanderthal men, they kept at least some of the women. This Tabun woman was possibly the wife of the Skhul man, or perhaps the nurse of his children. In South Africa we find the same thing has happened again and again. In caves we may find most of the skulls those of Koranas, but with those of Bush women; and it is the same in old graveyards, where there are many Koranas and some quite pure Bush women and even Bush men.

It is interesting to note that all known Neanderthal skulls are of comparatively late date. True, we have the Mauer jaw of early date, but it is by no means certain that this is a Neanderthal jaw. The Steinheim skull has also been regarded as an early Neanderthal type, but judging by the figures that have been published it does not seem to me to be a Neanderthal type at all.

Then it is remarkable that except in the Mediterranean regions, Europe and Turkestan, no Neanderthal skull has ever been found. In Java we have Pithecanthropus, and the Wadjak skulls and the Ngandong skulls, but no trace of Neanderthals. In Equatorial and South Africa we have many early human skulls, but again definitely no Neanderthals.

In East Africa, Leakey has made two extremely important discoveries of early man—the Kanam man and the Kanjera man. The Kanam jaw is, unfortunately, very imperfect, but there is no doubt that it is a human jaw, and it is not Neanderthaloid, and it is said to have been found in beds that are of Lower Pleistocene Age. Kanjera man is known by the fragments of two skulls said to have been found in beds of Middle Pleistocene Age. Though the two skulls are badly broken they can be restored with considerable confidence, and the interesting point about them is that they are both typically *Homo sapiens* without a trace of any Neanderthal characters.

When Leakey announced this discovery most English scientists accepted Leakey's statements that he had found these non-Neanderthal human remains in beds that were Lower and Middle Pleistocene. But a little later Professor P. G. H. Boswell visited the localities in East Africa, where the remains had been found, and he considered that there was some doubt as to the precise spots where the remains had been found, and

owing to the clayey nature of the beds he was doubtful as to the human remains being contemporaneous.

Having fully considered Boswell's doubts and Leakey's reply, I have no hesitation in taking Leakey's side in the dispute. Leakey says he found the Kanjera skull fragments on the surface of a weathered bank, and that on working into the undisturbed bed other fragments were discovered, showing, it seems to me, quite conclusively that the remains were contemporaneous with the bed in which and on which they were found. It may be regrettable that Leakey did not take photographs of all the fragments before he picked them up; but even though he did not, I accept his account of how and where the fragments were found, and also believe that these fossilised human skull fragments are remains of Middle Pleistocene Man.

It is unfortunate that we frequently see a tendency in even some eminent scientists to doubt the honesty or at least the skill of other workers. In the case of the Galley Hill skull, Heys, who saw the skull *in situ*, and Elliot, who saw the spot where the skull had lain, were both quite satisfied that it was in undisturbed gravel; but while Newton and Sollas and Keith all considered the skull as contemporaneous with the gravel, others doubted the evidence of the discoverers; and to day most follow the lead of Sir John Evans and Sir William Boyd Dawkins in regarding the skull with suspicion.

If we accept Leakey's finds as evidence that man of the modern type lived in Middle and even Lower Pleistocene times then it would seem as if this type of man is much older than the Neanderthal; and another possibility arises. Is it not possible that Neanderthal man has been evolved from some type of modern man?

Neanderthal man has been regarded by the large majority of anatomists and anthropologists as a primitive type of man. It has large gorilla-like ridges above its eyes, and it has a very prognathous face, and a few characters in the skeleton are in keeping with these supposed primitive characters. But if we consider these characters critically we see reason for doubting if any of them is really primitive.

The great gorilla-like supraorbital ridge is really not a primitive character at all. The gorilla has them well developed and the chimpanzee has them much less marked. The orang has scarcely any supraorbital ridges at all. The large baboons have ridges fairly well developed; but nearly all other monkeys have very small ridges or none at all. The character is certainly not a primitive character. Further, we have, as will be shown, good reason to believe that man is not at all closely related to the gorilla or chimpanzee, and that the ridges we find in the Neanderthal man must have been developed quite independently from an ancestor which had them only feebly or not at all developed. Large supraorbital ridges are, in my

opinion, of no morphological significance; they are merely concomitants of massiveness.

In small deer and antelopes the antlers and horns are small; in large deer and antelopes antlers and horns may be enormously developed, and far larger relatively than in the small forms. In the extinct Titanotheres we find exactly the same rule. The small Titanotheres had quite small bony outgrowths on the snout, or none at all. The large Titanotheres, like Brontotherium, had huge hornlike out-growths; and we find, in addition, to the nasal horns, bony out-growths on the cheek bones. We find the same rule in some other groups, even in the large Anomodont genus Aulacocephalodon.

Then it is held that the face of Neanderthal man is also more gorilla-like than like that of modern man. But here again the condition is not primitive. It will, however, be said that the chin is unlike that of *Homo sapiens*, and like that of the anthropoids. Certainly some Neanderthals have no chin; but others have a little bit of a chin. I incline to think that even the absence of chin in the Neanderthals is a secondary character. When the face took on the prognathous development the teeth were carried forward, and the chin disappeared as a prominence.

The chin in man is a unique character, not met with in any other mammal. It doubtless arose from a lower jaw like that found in Australopithecines when the teeth became much reduced in size. The lower part of the jaw remained little altered owing to its having to accommodate the muscles at the base of the tongue, and when the teeth became reduced the upper part of the ramus had to become shorter than the lower, and as a result a chin developed. In Neanderthal man the reverse process probably took place, and with the tooth area being carried forwards the chin disappeared.

Another interesting Neanderthal character is the taurodont character of the molars. But this again is not a primitive character, and apart from the taurodontism the Neanderthal teeth do not differ appreciably from those of *Homo sapiens.*

The most important contributions that South Africa has made to the problem of the origin of man started with the discovery, in 1924, of the now famous Taungs skull. This was described by Dart in the beginning of 1925 as the representative of a type of anthropoid, somewhat intermediate between the chimpanzee and man, but nearer to the ancestor of man than any other known form. Most European scientists considered that Dart had made a mistake, and that the Taungs ape was really a variety of chimpanzee. This was the first opinion of Keith, Elliot Smith, Smith Woodward, Duckworth, and Robinson. From the first I supported Dart's view, and soon Sollas, who had inclined to the view of Elliot Smith and Keith, also came to regard the Taungs ape as not allied to the living anthropoids but near to the ancestor of man. Then

Elliot Smith also came round to this view, and in America Gregory also supported Dart's view, while Romer said that whatever Australopithecus was it was certainly not a chimpanzee or a gorilla. Adloff went further than Dart and held that it was a true primitive man.

The difficulty of coming to a definite view of the affinities of Australopithecus was largely due to the fact that the skull and only known specimen is that of a child comparable to a human child of about five years.

As there seemed to be no other way of convincing the world, I resolved, in 1936, to hunt for an adult skull. There are numerous caves in the dolomitic limestone of the Transvaal, and I started on my hunt. I knew that even if I did not find any evidence of primitive man or of his possible ancestors, I was sure to find many new Pleistocene mammals, as very little had ever been done before in this direction. Within a few weeks I had discovered nearly a dozen new extinct species, and at least one new genus.

Then I heard of the limestone workings at Sterkfontein, near Krugersdorp, and went there with two Johannesburg students, G. W. H. Schepers and H. de Riche. The manager of the limeworks was Mr. G. Barlow, who had once worked at Taungs, and he knew something about the Taungs skull. I got him to promise to keep a sharp look out for anything like the Taungs ape revealed by his blasting operations. Within ten days he had discovered the brain cast of an allied form. A long search revealed most of the skull, but without the mandible, of what proved to be a new form of higher primate allied to Australopithecus. And this new specimen was an adult. In my first published account I described it as a new species of Australopithecus. Later I made it the type of a new genus, and called it *Plesianthropus transvaalensis*. It is unnecessary here to give any detailed description.

For nearly two years I visited Sterkfontein every week, except while on a visit to America in 1937, and I made many other interesting discoveries. I found a beautiful maxilla of what I regard as a female, and a maxilla of what I consider to be an old male with extremely worn teeth. Many isolated teeth were discovered, and the adult dentition is now almost fully known. Of the milk dentition we only know half of one molar. Then I was fortunate in finding much of another brain cast, and part of a third. We also got a few post-cranial bones, the most important being the distal end of a femur and a carpal bone.

In 1938 an even more important discovery was made at an adjoining farm Kromdraai. Here was found nearly the whole of the left side of an adult skull of still another type of higher primate. In addition to the skull we were fortunate in getting a beautiful mandible, the distal end of a humerus, and proximal end of an ulna, and a number of finger bones. Then in 1941

we were further fortunate in getting part of a lower jaw of a very young child with the beautifully preserved milk teeth. I described the Kromdraai skull under the name *Paranthropus robustus*, and I regarded it as allied to the Taungs and Sterkfontein skulls, but belonging to a third new genus.

Some English scientists considered that I was rather daring in putting both the Sterkfontein and Kromdraai skulls into new genera, and thought it likely that the skulls I had found would prove to be only adult specimens of Australopithecus. Now that we know the lower milk dentition of the Kromdraai ape, we can at once see that it is very different from the milk dentition of Australopithecus, and also from that of Plesianthropus. Plesianthropus is more nearly allied to Australopithecus. Paranthropus differs so markedly that we may even have to put it into a new family or sub-family.

These three South African higher primates all show interesting affinities to man. Geologically they all seem to be too recent to be human ancestors. The Taungs ape is almost certainly very much older than the others. I regard it as Lower Pleistocene, or possibly Upper Pliocene. Plesianthropus and Paranthropus are both, in my opinion, Middle Pleistocene forms, but these must differ greatly in age. The associated faunas are almost entirely different.

Though these fossil primates may not be in the human line they represent a group which probably survived from the Pliocene, and, in my opinion, it was from some Pliocene member of this group that man arose. Gregory and Hellman have placed these South African forms in a new family, which they call the Australopithecinae. The group is manifestly not at all nearly related to the living Anthropoids, and must be related to the ancestor of man.

The first lower milk molar of man has four well marked cusps, and so has the corresponding tooth in Australopithecus and Paranthropus. In the gorilla this tooth has only one cusp. In the chimpanzee and orang there is one main cusp with rudiments of two others.

The close resemblance of all the milk teeth of the Australopithecines to those of man, seems to force one to the conclusion that man is closely related to this family and not closely related to the gorilla and chimpanzee. Weidenreich has argued, from the structure of the human adult lower premolars, that man cannot be closely related to the living Anthropoids, where the adult premolars differ essentially. And this view is fully confirmed by the structure of the adult teeth of the Australopithecines, besides many other points of the skull structure.

Dart had argued from the apparent habits of the Taungs ape, that it must have been mainly bipedal; and this is borne out by what we know of the limb bones of Plesianthropus and Paranthropus. In my opinion the Australopithecines were almost as fully bipedal as man. They were certainly not forest animals.

When the Taungs ape lived, Bechuanaland was much more desert than to-day, with a rainfall of probably under six inches. Even the Transvaal in Middle Pleistocene times, was certainly not forest country. The Australopithecines must have lived, like baboons, among the rocks and on the plains.

Though they were not yet men these South African fossil types were nearly human. They had brains of from 450 cc. to 650 cc., and the brains were highly convoluted, and though very different from those of the Anthropoids, very similar to the Pithecanthropus brain, but smaller. Still Von Koenigswald considers that the female Pithecanthropus had a brain perhaps as small as 750 cc., so that the gap between this and the Paranthropus brain, of at least 650 cc., is not a large one.

The South African discoveries have shown, I think, conclusively, that man cannot have been descended from any of the typical Anthropoids, and has almost certainly come from a pre-Dryopithecid of Oligocene times. If this be so, it seems improbable that *Homo sapiens* passed through a Neanderthal-like stage; and makes it not improbable that Neanderthal man has been derived from a human type, such as the Wadjak by a mutation, perhaps due to arctic conditions, which resulted in massiveness of face and generally acromegalic characters.

The descent of man seems to have been by stages, such as an Australopithecine type, next a Pithecanthropus-like type, then a Sinanthropus-like type, and then an Australoid type of *Homo sapiens*.

## INDEX TO TEXT FIGURES.



1, 2, 3, 4, 5, 6, cusps; AC, anterior cusp; IC, intermediate cusp; F represents the teeth in a Bushchild in the Anatomical Department, Witwatersrand University, where the cusps are almost exactly as in Australopithecus. The Kromdraai milk teeth are seen to differ markedly from those of the Taungs Ape-man. The Sterkfontein first milk molar differs considerably from those of the other two known Australopithecines and it resembles the corresponding tooth in some Kafir children. It belongs to the jaw which has the beautifully preserved canine which is certainly not human.

Fig. 1.

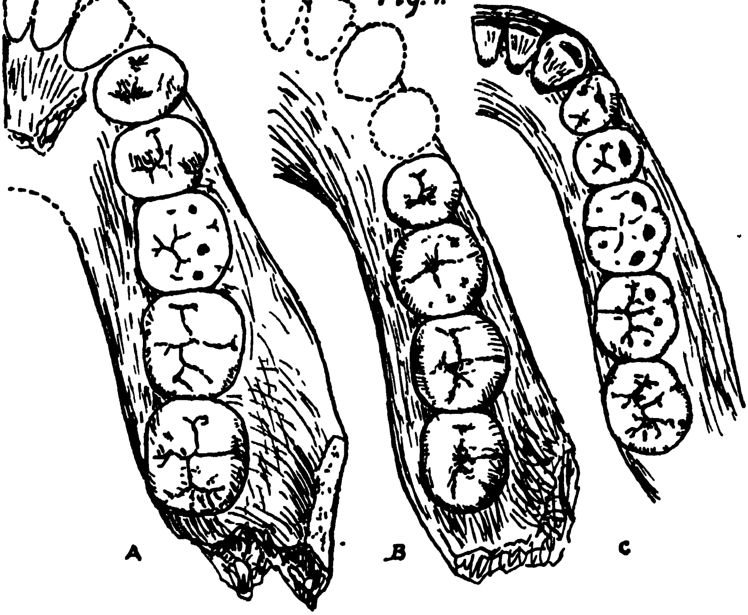
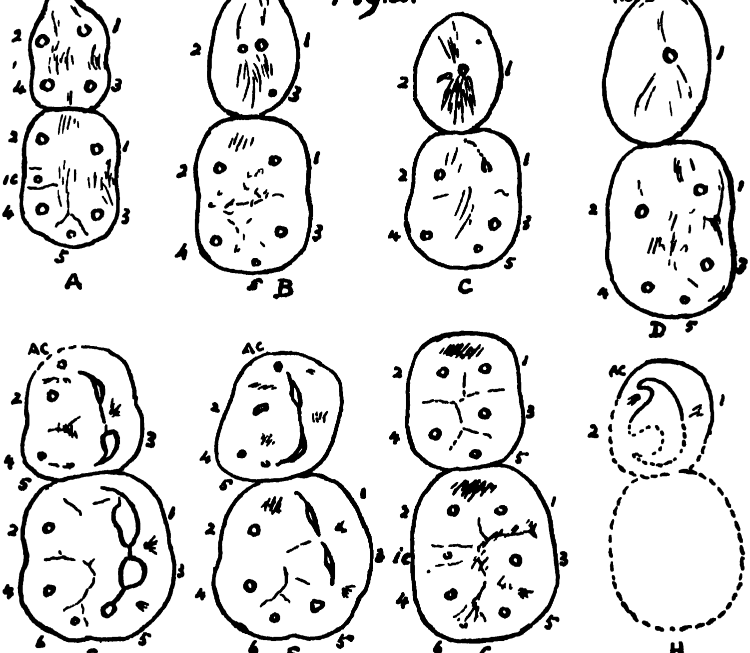



Fig. 2.



SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 81-97, November, 1943.*

# LIBRARIES AND SCIENCE

BY

PERCY FREER

*Presidential Address to Section F, read 29th June, 1943*

## INTRODUCTION

Under the auspices of this Association the first conference of librarians and those interested in libraries in South Africa was held on Tuesday, 5th April, 1904, at Johannesburg, when the late Dr. Reunert presided. There were also present the late Howard Pim (then Chairman of the Johannesburg Public Library), the late Bertram Dyer, Mr. John Ross (then of Pietermaritzburg, and but recently retired from the Kimberley Public Library), and others. The late Sir Perceval Laurence wrote, but did not read the inaugural address, in which he urged the inauguration of a South African Library Association and the starting of a library journal.[27] The late Dr. Innes, Dyer, and other speakers deprecated any such attempt, and it was unanimously agreed to ask the Council of the Association to arrange a special sub-section of Section D (!) at future annual meetings to deal with the question of libraries.[40] At the next year's meeting Dyer contributed another interesting paper on "Libraries for scantily populated districts."[12] (He had read one to the first meeting in 1903 at Cape Town).[13] I record these contributions of forty years ago lest you should think that the present address had been better entitled: "Science and the Frustration of Libraries." I am not aware that the Association again acted as publishing medium for South African librarians until 1936, for Mr. Kennedy; [26] and again in 1941, when Mr. Asher read his Presidential Address here on "South African Libraries."[2] Meanwhile the South African Library Association had been defiantly launched in 1930,[41] and its own journal started three year later.[39a]

This address, as originally announced, was entitled "Libraries and the Advancement of Science," primarily because I wished to associate my subject with the name of the Association. But a little thought indicated that our rudiments of a service might more aptly be termed "Libraries and the Frustration of Science." Then there appeared evidence to show Science's claim to the advancement of libraries; and again of their frustration by Science. And finally of Science herself being the common enemy. The upshot was that Council allowed the change of title, and so provided me with an ample and

flexible if not scientifically constructed framework for the subject matter of this address.

Before proceeding may I define " Science," as here understood, to connote any branch of knowledge, as it does in French. Our Russian allies, in turn, regard as dangerous and unscientific any distinction between pure and applied science, and ask how any genuine science (that is to say, any real knowledge of the universe) can be " pure " in the sense of having no relation to the external world. (47)

### LIBRARIES AND THE FRUSTRATION OF SCIENCE

With this introduction allow me now to quote from the Report of the Interdepartmental Committee on the Libraries of the Union: " In library development the Union of South Africa lags behind the rest of the civilized world. At the root of the trouble is the general adherence of South African libraries to the Subscription System. This should be abandoned for a Free System, and the benefits of libraries made available to every citizen." (43) It has not yet been abandoned, and the adherence has endured for 125 years. Surely a longer sentence than we deserve! But perhaps not, for we continue to connive at the annual payments from public funds to those exclusive libraries; (10) to subscription libraries " reluctant to open the doors to the public, so that the vested interests of subscribers . . . prevent . . . the libraries from becoming popular institutions." (25) For just so long as this iniquity continues do we postpone the inauguration of a library system which, if it cannot be exemplary, would be better based on any other system than that of eighteenth century England. " For literary culture a government can do most by . . . promoting libraries that place books within the reach of those who cannot buy . .," (47a) not by heeding St. Matthew's " For whosoever hath, to him shall be given. . . ."

It was the late Right Hon. Sir John Wessels who said that " in the absence of Union library legislation the South African library position must remain chaotic." (49) There is indeed almost a total absence of any co-ordinated system, and actual competition between libraries and librarians only gives way to co-operation in the case of institutions of the same town. Fortunately your demands are modest as yet, otherwise the lack of a proper system must have been exasperating, if nothing more. Since war broke out, and the oversea markets closed one after another, we had to manage as best we could with what, more by good luck than judgment, was already present in the country. Occasionally, it is true we could still remedy a deficiency by obtaining from London, after much delay, a photostat copy of an important article. For the rest, we have had to share with Australia and New Zealand, the disadvantages of isolation from the literary resources of Europe and America. (42)

The Interdepartmental Committee also recommended the appointment of a National Library Board to advise the Union Government on matters affecting the organisation and co-ordination of the library system of the country as a whole, and emphasised that " the efficiency and success of any library service . . . depend mostly on the quality of its personnel [since] the demands made upon the librarian of a modern large library are very great."[43a] In the meantime it is becoming more and more difficult to attract scholarly people to the library profession owing to prevailing low salaries; our scales fail, e.g. to recruit science graduates to our ranks, just when science is becoming still more specialised. That the training, the status, and the conditions of employment of librarians are matters as important to you as they are to the present victims, will emerge later. We do not want to see ever again the establishment of " a university without a library "—or a librarian. The 1928 Commission felt " that . . . the library facilities at the existing institutions [were] inadequate. At some they can hardly be said to exist."[44] Such conditions, by the way, justified the sending of post-graduate scholars overseas; as they did not warrant the award of higher degrees locally so long as the necessary literature was unobtainable in the country.

Turning to a bibliographical comparison of the world's output with local stocks, it has been computed that during the cradle days of printing alone some 40,000 editions appeared; and by 1911 the figure had reached 25,000,000, but of which the Brussels Institute had recorded only 14,000,000 by 1928! Professor Hutton, writing last year, stated that the National Central Library in London commanded over 21½ million books for purposes of inter-library loans, these representing the stock of the English public libraries, plus nearly 150 " outliers," i.e. special libraries, together with about 35,000 sets of scientific periodicals.[22]

It does not follow that, because of a smaller population our own requirements are more modest. Yet, " in 1933 the Librarian of the State Library, Pretoria, said that of the 1,780,000 books that were recorded within the libraries of the Union, something over 1,000,000 could be regarded as surplus."[45a] (He may have meant duplicated, superseded, or fictional; certainly few of them have passed the test of informed selection).

Book selection is one of the most important and exacting of a librarian's duties, and, as applied to scientific literature, is often beyond him. Hence Book Selection Committees are largely composed of university professors and other specialists. Admittedly—and obviously—there are a few competent librarians in the Union, but which, among them, would dare, unaided, to skim the cream of the world's literary and scientific output, implying a working knowledge of every important language, and an insight into every subject under the sun? Science has

no geographical boundaries, but language barriers persist, and relief is urgently needed, whether it come through "Basic," "Interlingua,"(35) or another medium as internationally understood, as, for example, is $H_2O$.

The Sub-committee on Bibliography of the International Committee on Intellectual Co-operation of the League of Nations approved in 1924 the annual publication of an abridged list of notable books published in the different countries of the world, which could be regarded as representative of the achievements of each country in the various fields of intellectual work. And so for the next six years *Notable Books* was published, listing at the outset 352 titles from 20 various countries. The Union's list appeared for the first time in the volume for 1925; it was allowed to make honourable mention of 10 titles only, because it was then publishing less than 2,500 titles per annum.(29)

What Professor Gilbert Murray said in 1924 about the relevance of bibliography to the cause of intellectual co-operation will bear repeating now:

> "It is by reading one another's books that we get into one another's minds; it is by the co-operation of scientific and philosophical research; it is by co-operation in building up literature and art in our different countries that we can hope to get the minds of different nations moving again in concord and working towards something like a common end. The original idea of the Committee on Intellectual Co-operation was to try to help the intellectual life of Europe, which had been torn in pieces by the passions of the war, and by the economic and other interruptions caused by the war, to flow again in something like a common current."(33)

Similarly the Times Literary Supplement's "Foreign Section"(41b and 5a)

> "An attempt to provide intelligence of world-wide literary events in the conviction that international understanding in the profoundest sense of this term, requires more intimate contacts between peoples than are vouchsafed by economic and political interests."

> "It is by books that mind speaks to mind,
> By books the world's intelligence grows."(29a)

The influx of books into South African libraries must exceed, of course, the rate of one book per day, or one parcel per customer per week! (44a) Of important books relating to science a modest 14,000 titles constitutes the annual minimum output. But we lack the machinery to select even these. Nevertheless, I seriously contend with Mr. Asher (1) that the matter of their selection, importation, diffusion, and ultimate disposal are surely not the concern of librarians alone. Let me tell you how one sister dominion is viewing this problem.

The New Zealand Book Resources Committee wants a complete coverage of recent and new publications, and coverage of all back publications which have not become out-of-date or been superseded, i.e. it aims to put into New Zealand's stock every book of value, not the "best book" in someone or other's estimation. The Committee recommends that Pure Science and Applied Science and Industry should be the subjects to be covered first. This scheme is limited, as yet, to books in the English language. None the less it sets one landmark in library history, as does the New Zealand Government set another in their recognition of an efficient library service as an essential part of the equipment of a modern nation.([34])

Dr. Keppel would have us remove two other factors which at present handicap book selection. He says: "Librarians can make themselves more useful than they now are in recognising the need for books as yet unwritten, books on important subjects that should be authoritative, simple and readable, and in extending the influence of their profession to see that such books are written and published."([11])

Any partial fulfilment of these aims will be neutralised if the ultimate disposal of the book stock, so painstakingly acquired, is not studied with equal care. It is my opinion that one copy, the best one only, of every work of non-fiction that ever found its way into this country should be preserved in a Union Book Repository when the time comes to withdraw it from active service. Discarding relieves full and untidy shelves, and the librarian would more frequently exercise this necessary practice safely and with an easy conscience, in the knowledge that "by economies in building costs, by deferring of building programmes, in savings arising from removal of inactive volumes, by co-operative services, and as a permanent place for storage, the deposit library would make possible the heightened efficiency of libraries."([16]) The destruction of books and periodicals by enemy action has sent many prematurely out-of-print. The urgency of replacement by photographic reproduction is a drain on the limited paper available and enforces the plea to publishers ([3a]) to ask those subscribers who do not themselves conserve their copies to return them, for the purpose of completing the files of bombed libraries after the war.([4]) Even under stress of war printed items should only be thrown out for pulping with the approval of the one competent body, the South African Library Association.

As every coin has two sides, so, in fairness to my colleagues, let us view the reverse.

### Libraries and the Advancement of Science

There has been one important scheme working to our mutual advantage for some years. I refer to the Inter-Library Loan System, whereby any bookish request not met by your local library is transmitted to all stations through the Central

Library at Pretoria. It powerfully augments the very limited resources of any one institution. Librarians are painfully aware of its limitations. The scheme is still very far from being complete. Its maximum efficiency awaits several improvements, notably:

1. Large additions to South Africa's book store.
2. The completion of a master-catalogue of every non-fiction book in the libraries of the union. (At present about 100,000 titles have been indexed at the State Library, Pretoria).
3. An enlargement of our holdings of periodical publications.
4. Publication of the new edition of Lloyd's List.([17]) (As its Honorary Editor, I welcome this opportunity to acknowledge the generous contribution of £100 made towards it by the Associated Scientific and Technical Societies).
5. Compilation and publication of a complementary volume, covering the Humanities.

Until items 2, 4 and 5 are available, obviously all attempts at both book buying and discarding are risky.

The study of what is already known is the first step in discovering the unknown. To this end the authorities tell us that of the 24,000 titles in the *World List of scientific periodicals* only 15,000 are of first-rate importance. But our joy is shortlived on learning that these alone contain 750,000 separate contributions, i.e. about one good article per journal per week. Obviously the task of keeping up-to-date with, and surveying so unwieldy and vast a stock of publications is to-day beyond the power of an unaided individual.([22]) You will now appreciate a statement made by Dr. Esdaile, the retired Secretary of the British Museum, to the effect that " the periodical has added a new terror to research ";([15]) and *Ecclesiastes* (1:18): " For in much wisdom is much grief; and he that increaseth knowledge increaseth sorrow "; and Keats':

" Where but to think is to be full of sorrow
And leaden-eyed despairs."

" In all this enormous accumulation of material the student would lose his way, and waste years before finding even part of what he needed. were it not for bibliography."([15a]) Bibliography has become a science; its principal aim is to serve the other sciences, or rather intellectual activities. And whilst avoiding catalogue enumeration I should like to name here at least the main tools at your disposal, most of them designed to guide us through that flood of articles which you persist in contributing to scientific periodicals:

The Royal Society's " Catalogue of Scientific Papers " (1800-1900); ([39]) " International Catalogue of Scientific

Literature " (1901-14); [24] " Poggendorff "; [37] U.S.A. Surgeon-General's " Catalogue " (1880 + ); [45] " Industrial Arts Index " (1913 + ); [23] and the Science Library's Weekly Bibliography of Pure and Applied Science [1931? + ] [31].

Then of the so-called " union " lists, in addition to the " World List " [50] (and its complementary volume, " Roupell ") [38], the most important are: " Gregory " (80,000 titles), [20] " Pitt " (35,000), [36] the Science Library's " Hand-list " (9,000), [30] and the new Lloyd's List (which I am calling a " Catalogue of Union Periodicals ") [17] with 6,000 titles. These furnish the means of surveying the main research done and recorded.

This is not the end of your trials and tribulations. But a change of sub-heading is much overdue. It should now surely be

SCIENCE THE COMMON ENEMY

In order to extricate yourselves from this maze you launched the Abstracting and Indexing journals, with confusion worse confounded. In 1937 there were already 300 such periodicals, yet they handled merely one-third of the scientific papers concerned, missing the other two-thirds, partly from inability to assess their importance, partly through overlapping, the language barrier, and other reasons. And when my same authorities analysed the periodicals containing articles on a special subject, e.g. Lubrication, they found the literature to be despairingly diffuse. Instead of being conveniently confined to the 20 most likely ones, it was distributed among 840! [6-7, 22] Appalling as are these statistical data, the fact remains that if scientists neglect the work of others in their own subject, they may spend months and years of work trying to solve an already solved problem. The final blow falls when I tell you that of these 300 Abstracts and Indexes only 41 of them are at your disposal somewhere in South Africa.

" At one time," says Professor Hutton, [22] " I flirted with the idea of founding a new ' Society for the Suppression of Redundant Periodicals,' which should be a mine of wealth to the promoter, for many of the periodicals are mainly kept alive by advertisement income, and I feel sure advertisers would gladly pay a fraction of what they would save, to a Society providing the necessary lethal weapon to strangle new periodicals at birth, or as soon thereafter as possible." Indeed, there even exists at least one periodical carrying " Births and Deaths " in the periodical field as one of its regular features. [9] Your remaining hope of keeping up-to-date with the latest developments may be found in volumes of Recent Advances, Reports of Progress, the Year's Work, or in H. G. Wells' " Idea of a World Encyclopaedia," [48] while courting the attendant dangers of superficiality, and becoming a jack of all trades, but master of none. In the meantime it is an ill wind that

blows nobody good, for the services of librarians become increasingly indispensable!

## Needs and Opportunities

Not the least of the claims to glory of King Alfred is the fact that he cared for bookcraft. He, too, claimed that books should be given to the people, and he had a whole library of classics translated from Latin into English, so that those who did not know Latin might be able to read the sacred books in their own language.([18]) Similarly to-day the Bureau of Animal Population at Oxford is translating into English many ecological works emanating from the U.S.S.R.([11]) "During 1932 the number of separate titles published there reached the figure of 55,000, with a total issue exceeding 500,000,000 copies—an aggregate product which . . . probably exceeds the output for the year of all the publishers in the rest of the world."([47a]) Another example of the importance attached to current Russian literature is the publication of a war-time guide to British sources of specialised information, compiled by ASLIB at the request of the British Council on the recommendation of the Anglo-Soviet Scientific Collaboration Committee.([5]) Shall we continue to disappoint our inquirers, or shall we attempt an intelligent anticipation of growing demands for more Russian scientific literature?([40a]) So that, in future, paraphrasing Mr. Churchill: "Instead of, as hitherto, getting somewhere very late, with very little, we might for once arrive first, with the most. Or shall we remain as "They who do not feel the darkness [and] will never look for the light?"([8a]) This time you may condone as unintentional the inability of South African libraries to furnish required information, whereas a recurrence may well be mistaken for sabotage.

Mr. Hofmeyr, speaking as Minister of Education to the Senate, on 31st March, is reported ([37a]) as saying of research: "Progress was being made . . . but he was not satisfied with the present position. . . .He doubted whether there was sufficient co-ordination between the various research organisations, or whether there was sufficient encouragement. The National Research Board had come to the same conclusions, and had made certain recommendations which were being considered. In these times, especially, no country could hope to take its part among the nations of the world unless it made proper provision for research work." In my opinion this postulates a bibliographical basis, which, if properly planned, is capable of turning a defeat into a victory, for, as Disraeli said: "A book may be as great a thing as a battle." At the 1937 ASLIB Conference a member cited the case of the production of glycerine: "In the days of the 1914-18 war the strategy of the Allied armies was based on the supposition that the enemy would exhaust the fat supplies from which glycerine was produced. Had the literature on the subject been properly accessible it might have

been made known to the Allied command that a method had already been described in a certain paper for the production of glycerine from sugar. Germany was, in those days, in fact, already producing glycerine from sugar."([6a]) Alas, the new *Catalogue of Union Periodicals* reveals the fact that not one of the 77 participating libraries possesses a single periodical on soap!

With plans to the right of us and plans to the left of us, the almost daily announcement of yet another scheme for post-war reconstruction would merely become monotonous were the matter not so serious. For either the concomitant bibliographical apparatus is presupposed, or it is entirely overlooked. The literature prerequisite for the study and ultimate expansion of agriculture, education, housing, industry and so forth may be largely lacking, exposing such a handicap as will not easily be overcome. Still the Government sets up one commission after another, appoints committee after committee, subsidises this concern and that, and thus increases the demand for literature on the new subject interest aroused, to the chagrin of the inquirer and the embarrassment of librarians. (That the Government is not unaware of the importance of literature is evidenced by the publication of six *Memoirs of the Geological Survey*, wholly devoted to the bibliography of South African geology, by A. L. Hall (Pretoria, Gov. Print., 1922-39), which had been anticipated in 1897 by the Cape Geological Survey's *Bibliography* . . . compiled by H. P. Saunders). This is putting the cart before the horse. Small wonder then that

> " The best laid schemes o' mice and men
> gang aft a-gley
> An' lea'e us nought but grief and pain
> for promised joy."

Research work implies trained personnel, properly equipped laboratories, and efficient libraries. As for the last the emphasis to-day is more on their informational and educational services. Only a highly trained staff and one commanding the necessary resources can offer such services. For the advancement of science our resources must be augmented, firstly in order to lessen the gap between the 6,000 titles of the *Catalogue of Union Periodicals* and the 15,000 acknowledged as being of international importance; secondly, as far as the acquisition of those 14,000 books goes. Would Mr. Hofmeyr have these desiderata located in a special Service Library attached to the National Research Council and Board, or, to form part of the largest existing science library, namely, the Seymour Memorial Library; or divided equally between the two national libraries; or distributed among the present university libraries; or assigned in roughly equal proportions to the proposed regional headquarters of the different provinces?

### National Library System

And here let it be emphasised that State-aid must not begin and end with these national libraries. The burden of supplying the new regional libraries in their task of feeding the rural stations and other outlying posts, must, for some years, fall upon the existing urban libraries, so that it would appear most unfair to expect the parent provinces and municipalities to defray all the expenses incurred in carrying out what is virtually a national duty, that is, to "Let the People Read"; ([37b]) to carry free of charge along this endless belt literature of a serious nature to the most distant citizen, of whatever race, colour or creed. For "without literacy," said Lenin, "no politics, but only rumours, small talk and prejudices."([47b])

### Library Advisory Committees

Unfortunately neither Natal nor the Free State has even yet taken over the administration of its public libraries, and both Pietermaritzburg and Bloemfontein are falling still farther from grace, for, in the opinion of the Interdepartmental Committee, only the South African Public Library and the State Library are able to fulfil the obligation implied of preserving all the material received under the Copyright Act, and it recommends that full privileges be restricted to Cape Town and Pretoria.([43a])

The Cape and the Transvaal Administrations, on the other hand, brought public libraries within their jurisdiction in 1913. They have also agreed in principle to the adoption of the recommendations of the Interdepartmental Report and have appointed Library Advisory Committees. The Transvaal Committee, as the Provincial Secretary said: "In next to no time . . . had persuaded the Provincial Administration to obtain the services of a Library Organiser . . . to assist . . . in devising a really effective library system for the Transvaal. . . . It is proposed to divide the Transvaal into, say, 15 regions and to have a regional library in each of these centres. . . .To begin with, the Organiser has suggested 9. . . ."([35a]) The Cape has not yet disclosed its plans.([46a]) But at least you begin to see "the shape of things to come," and how Mr. Hofmeyr's various research organisations could be linked up with a national library system.

It was one of Mr. Asher's contentions that the distribution of South African industries should influence, if not decide the location of their relevant literatures.([2]) In this connexion Durban, e.g. might assume greater importance than Pietermaritzburg. Then, too, a strong case could be made out for the continuance and further development of the special libraries, even when in close proximity to large general ones, e.g. on Sugar at Mount Edgcombe, Botany at the Division of Plant Industry, Paper at Endstra, Veterinary Science at Onder-

stepoort, and so on. Though unity is strength it ill behoves me to advocate putting all our eggs into one basket. But please see that the special libraries do strictly confine their collecting to the subject in hand, and not take all knowledge for their province. The development of a Central Science Library would free them to aim at completeness within their proper spheres.

And here I see a prime, if delicate function of the National Library Board, i.e. with the least possible interference with local autonomy, of making the attempt to supervise the acquisition and apportionment of literature vital to advanced research, whether it be obtained through exchange or by purchase. The new *CUP* (17) will disclose numerous anomalies, much unnecessary duplication and annoying imperfections; in brief, many bits and pieces of scientific periodical literature, variously shared by the 77 libraries which generously participated in the work. I hope that one result of publication will be a consolidation of broken runs in order to achieve a fair geographical distribution, advantageous to all scientists, of the resulting few complete sets. I am a strong advocate of the closest co-operation in the purchase of expensive periodical literature. A good sound set of one important title may easily cost £1,000, and we lack not less than 10,000. Our past hit and miss practice in this respect has not resulted in libraries contributing so much to the war effort as might otherwise have been the case. At least let us stop short of competing against the bombed libraries for the few sets that escaped destruction.

### Science and the Advancement of Libraries

Hitherto I have only incidentally credited Science with the advancement of libraries. It is now fitting to specify instances of our debt. What are the relations of the scientists to the physical book, to its ingredients— paper, printing, illustrations, and binding—and to its preservation, etc.? The Frenchman, R. A. F. Réaumur, of thermometer fame, the Pliny of the eighteenth century, after observing the nest-making of wasps, suggested wood as a paper-making material in 1719. He could hardly have been expected to anticipate its consequences. The generally accepted derivation of the term "book" makes the tree its parent, but the use of mechanical wood pulp in book-making exposes the tree to a charge of infanticide. To-day's excessive wear and tear on books, their publication in ever-decreasing editions, (8) their restricted admission into this country, (42) these factors alone are distressing enough, but they fade into insignificance beside the perishing of literature. It seems a poor policy to send books to libraries for preservation when neither such preservation is a condition of copyright deposit, nor the paper they are printed on is permanent. (28)

There is at least one association, PATRA, devoting itself to the Printing and Allied Trades Research. Rival paper

technologists have set it other problems, e.g. how to make a paper that it is not just a " soufflé of pulp," containing 76 per cent air, or to prescribe such storage conditions as will not readily convert into a brick a book made of coated art-paper.

" With my twenty-six soldiers of lead I have conquered the world " is a phrase that has been attributed to Napoleon, among others, but not, so far as I am aware, to Gutenberg, the supposed inventor of printing, to whom the world last paid homage in 1940. But his Lilliputian army keeps watch for us over the wisdom of the past and safeguards the knowledge of to-day for future generations. And the " Battle of the Books " goes on. (32, 46)

The basic processes of illustration have come full circle, from woodcut, through engraving and lithography, back to wood-engraving, with much help en route from the photographer and colour-chemist.

What the craft of the bookbinder lost when Michael Faraday severed his apprenticeship to it we can only hazard a guess. All we do know is that owing to subsequent deterioration someone prescribed a leather dressing to mitigate the sins of tanner and librarian alike. May I interpose here that we can justifiably look forward to the establishment of a large binding establishment in South Africa after the war.

Students of library classification are familiar with the names of Gesner, Bacon, Ray, Linnaeus, and the late Karl Pearson. The names of other great scientists are associated with libraries, e.g. Sir John Herschel, to whom the idea of microphotography seems first to have occurred;(21) J. M. Smithson, F.R.S., who, in a fit of pique at the Royal Society's rejection of a paper by him in 1826, bequeathed the reversion of £105,000 to found at Washington " for the increase and diffusion of knowledge among men," The Smithsonian Institution, from which to-day we receive its valuable scientific publications; also Sir William Osler, historian of medicine, and for some years President of the Bibliographical Society. He bequeathed his valuable library to McGill, his Alma Mater. It was Sir Richard Gregory, assistant editor of *Nature* from 1893-1919, and editor till 1939, who said that " good and necessary books declare themselves slowly." But evidently the time lag became too much for him, and it is probably due to the suggestions made in his paper on " Standards of Book Selection in Science and Technology "(19) that librarians owe the *ASLIB Book-list*,(3) the most important guide to current literature in our field, because its recommendations represent the collated selections of more than 70 specialists. The corresponding American aid, *Technical Book Review Index*, is likewise confined to books in English.(41a)

Lastly, I must again mention Dr. R. S. Hutton, Goldsmith's Professor of Metallurgy at the University of Cambridge,

whose paper on " Sources of Scientific Information " has been freely quoted above.([22]) He is the new President of ASLIB and Chairman of its *Book-list* Committee. At last year's conference he read a paper on " The need for training in the use of libraries, in the curriculum of universities."([21a])

## Summary

The introduction recorded the early contacts between this Association and librarians. In " Libraries and the Frustration of Science " the Report of the Interdepartmental Committee was quoted to show that the backwardness of South African library development is due to adherence to the Subscription System, and Government aid to these exclusive libraries, misnamed " public," is challenged. The disadvantages of isolation are aggravated by the absence of Union library legislation, and a co-ordinated system. Stresses the need for a National Library Board to advise the Government on such matters. Importance attached to recruiting scholarly and trained personnel. Compares local with oversea resources. Emphasises the difficulty and importance of book selection. Mentions aims of the League of Nations, and the relevance of bibliography in the cause of intellectual co-operation. Invites attention to the grand project of the New Zealand Book Resources Committee, to import every book of value. Cites as a landmark the recognition of library service as an essential part of the equipment of a modern nation by the New Zealand Government. Advances arguments in favour of a Union Book Repository. " Libraries and the Advancement of Science " deals with the existing, though incomplete Inter-Library Loan System and the work of the Central Library, Pretoria, the diffusion of periodical literature, and bibliography to the rescue. " Science the Common Enemy " reviews the Abstracting and Indexing Services, and mentions a " Society for the Suppression of Redundant Periodicals." " Needs and Opportunities," overcoming the language barrier. Quotes Mr. Hofmeyr to the effect that " No country could hope to take its part among the nations of the world unless it made proper provision for research." Speculates as to the outcome. Argues that plans for post-war reconstruction are devoid of any bibliographical basis. Delicate apportionment of large-scale literary accretions to a National Library System. Postal barriers. Provincial Library Advisory Committees. Special libraries and a Central Science Library. Co-operation. " Science and the Advancement of Libraries " deals with scientists and the physical book: Réaumur and Paper, Printing, Illustration, Faraday apprenticed as a Bookbinder, Preservation of Printed Records. Other scientists and bibliographers, e.g. Herschel, Osler, Sir Richard Gregory and Professor Hutton.

## REFERENCES.


(1) Asher, S. B.: Economic aspect of a national library service: libraries for betterment. Johannesburg, The Author 1939.

(2) Ibid, South African Public Libraries. *S.Afr.J.Sci.*, **38**: 112-32 (1942); repr. in *S.Afr.Libr.*, **9** (4) 109—23 Apr. 1942).

(3) *ASLIB Book-list.* 31 Museum Street, London, W.C.1. **1** (1) Oct. 1935)+

(3a) *ASLIB Information.* (Oct. 1942) and (Apr. 1943).

(4) *ASLIB.* Salvage of Storage 1943. (*Memoranda*, Ser. A. No. 1).* Deals with the problem of accumulating stocks of the periodical publications of Learned Societies, Professional Institutions and Research Organisations, for the re-habilitation of British and foreign war-damaged libraries after the war. *Cf.* also *S.Afr. Libr.*, **9** ((2) 58 (Oct.. 1941) and **9** (3) 97 (Jan. 1942).

(5) *ASLIB*, Scientific and technical periodicals received from the U.S.S.R. Dec 1942.

(5a) *Books Abroad.* An international quarterly, Oklahoma **1** (1927)+

(6) Bradford, S. C.: Extent to which scientific and technical literature is covered by present abstracting and indexing periodicals. *ASLIB Conf.Procs.*, **14**: 59-71 (1937).

(6a) Ibid, p. 67.

(7) Ibid, Sources of information on specific subjects. *Engng.*, **137**: 85-86 (26 Jan. 1934).

(8) Brophy, J.: Britain needs books. London: National Book Council 1942.*

(8a) Buckle, H. T.: History of civilisation in England 1857. p. 334, quoted by Webb (47) p. 1003.

(9) *Bulletin of Bibliography.* Boston: Faxon, **1** (1897)+

(10) Cape of Good Hope. Molteno Regulations. *S.Afr.Libr.*, **8** (4) 146, (Apr. 1941), G.N. 508-1904, Circular I (Nov. 1921) Office of the Administrator; C.P. 1-1942: £13,988; Transvaal, T.P. 1942: £2,500; Union, U.G. 1-1943: 1943/44: £46,240 (to Libraries, Museums and Art Galleries). Allocations not specified. The two National Libraries are the S. African Public Library, Cape Town and the State Library, Pretoria. As from 1 Jan. 1933 the latter became a free library. ( (43) p. 43, footnote).

(11) Carnegie Corporation of New York. *Report of the President*, p. 17 1935.

(12) Dyer, B. L.: Libraries for scantily populated districts. *S.Afr.J. Sci.*, **3**: 523-28 (1905/06).

(13) Ibid, Public Library systems of Great Britain, America and South Africa. *S.Afr.J.Sci.*, **1**: 415-28 1903. Also published separately with 4 appendixes. Kimberley, 53p. 1903.

(14) Elton, C. S.: Voles, mice and lemmings. Oxford: Clarendon Press, p. 70, 93-95 1942. *Cf.* also: An index of translations *ASLIB Information*, No. 55: 1 (Apr. 1943); and lists of translations published by the Iron and Steel Institute, and by the Ministry of Aircraft Production.*

(15) Esdaile, A.: Student's manual of bibliography (2. ed.). London: Allen & Unwin, p. 324 1932.

(15a) Ibid, p. 16.

(16) Freer, P.: Address to the Third Triennial General Meeting of the South African Library Association. *S.Afr.Libr.*, **8** (1) 6 (Jul. 1940). *Cf.* also: *College and Research Libr.*, **3** (1) 3-8 (Dec. 1941) and *S.Afr.Libr.*, **10** (1) 6 (Jul. 1942).


* Not yet seen.

([17]) FREER, P., *ed.*: Catalogue of Union Periodicals [CUP] Vol. I, Science and Technology; ed. for the National Research Council and Board. *In the Press.* Work was completed last September (1942) and copies are expected daily.

([18]) GOLLANCZ, SIR ISRAEL: Anglo-Saxon bookcraft. 8. ser. of Annual Craft Lectures, at Stationers' Hall. First Lecture, p. 21 (1929-30).

([19]) GREGORY, SIR RICHARD: Standards of book selection in science and technology. *ASLIB Conf.Procs.*, **4**: 160-65 1927.

([20]) GREGORY, W., *ed.*: Union list of serials in libraries of the United States and Canada, *etc.* N.Y.: Wilson 1927. A second edition was published in June this year.*

([21]) HERSCHEL, SIR JOHN F. W.: New photographic process. *The Athenaeum*, No. 1341: 831 (9 Jul. 1853); *J. of documentary Reproduction*, **3** (1) 66-67 (Mar. 1940), and *S.Afr.Libr.*, **8** (3) 124-26 (Jan. 1941).

([21a]) HUTTON, PROF. R. S.: The need for training in the use of libraries in the curriculum of universities.*

([22]) HUTTON, PROF. R. S.: Sources of scientific information. *J.Instn. civ.Engrs.*, 1941/42, No. 4: 349-58 (Feb. 1942).

([23]) *Industrial Arts Index.* N.Y.: Wilson (1913)+

([24]) *International Catalogue of Scientific Literature.* 1st-14th annual issues, 1901-14. Published for the Intern. Council by the Royal Society, *etc.* London: Harrison 1902-19.

([25]) JONES, J. D. RHEINALLT, *In.*: Senate *Debates*, 21-25. Apr. 1941; repr. in *S.Afr.Libr.*, **9** (2) 45-57 (Oct. 1941), as: Senate Debate on National Library Policy.

([25a]) Ibid, p. 45.

([26]) KENNEDY, R. F.: Libraries and leisure. *S.Afr.J.Sci.*, **33**: 1086-89 (1937).

([27]) LAURENCE, SIR P. M.: Inaugural address delivered at the 1st Conference of South African Librarians. *S.Afr.J.Sci.*, **2**: 526-37 (1904).

([28]) League of Nations. *Committee of Experts for the Conservation of MSS. and Books. Amer.Libr.Ass.Bull.*, **26**: (1) 48 (Jan. 1932).

([29]) Ibid, *International Institute of Intellectual Co-operation.* Notable books, 1924[-29]. Paris: Les Presses Universitaires, 6v. 1926-30.

([29a]) LEWIS, C. T. C.: Story of picture printing. London: Sampson Low, p. 7 1928

([30]) London. Science Museum. Science Library. Hand-list of short titles of current periodicals. Part I: alphabetical; ed. by S. C. Bradford; 5 ed., H.M.S.O. 1938.

([31]) Ibid, Weekly bibliography of pure and applied Science. London: The Library [1931?]+ *Mimeographed.* Indexes every original article in a selection of some 150 scientific periodicals of more general scope. The Library also publishes (a) Bibliographical series of which Nos. 1-555 are indexed in *N.Y.publ. Libr. Bull.* **46** (8) 707-31 (Aug. 1942); (b) Weekly list of accessions.

([32]) MCALLISTER, G., *ed.*: The book crisis, by Sir Hugh Walpole, *etc.* London: Faber, for the National Committee for the Defence of Books (1940).

* Not yet seen.

([33]) **Murray, Prof. Gilbert**: Work of the Committee on Intellectual Co-operation of the League of Nations. *ASLIB Conf.Procs.*, **2**: 18-24 (1925).

([34]) New Zealand. Book Resources Committee. *N.Z.Libr.*, **5** (5) 117 (Dec. 1941); and *S.Afr.Libr.*, **10** (1) 16-17 (Jul. 1942).

([35]) **Peano, G.**: Vocabulario commune ad Latino-Italiano-Français-English-Deutsch pro usu de interlinguistas; ed. 2. Torino: Acad. pro Interlingua 1915.

([35a]) **Pentz, H. F.**: Public libraries of the Transvaal. *S.Afr.Libr.* **10** (3) 64 (Jan. 1943).

([36]) **Pitt, E. R.**, *ed.*: Catalogue of the scientific and technical periodicals in the libraries of Australia. Melbourne: Green 1930.

([37]) **Poggendorff, J. G.**: Biographisch-literarisches Handwörterbuch zur Geschichte der exacten Wissenschaften. Leipzig: Barth, *etc.*, 1863-. Bd. 1-6 (R) to 1931 (1938).

([37a]) *Rand Daily Mail* (1 Apr. 1943); ([37b]) ibid, (5 Apr. 1943).

([38]) **Roupell, M. G.**, *comp.*: Union catalogue of the periodical publications in the university libraries of the British Isles, excluding titles in the *World List.*, etc. London: National Central Library 1937.

([39]) Royal Society of London. Catalogue of scientific papers, 1800-1900. London: Clay 1867-1902; Cambridge: Univ. Press, 19v. 1914-25.

([39]) Royal Society of London. Subject index v. 1-3. Camb.: Univ. Press, 3v. *in 4* 1908-14.

([39a]) *S.Afr.Libr.*, Johannesburg **1** (Jul. 1933)+

([40]) South African Library Conference. *Libr.J.*, **29**: 368-69 (Jul. 1904).

([40a]) *Special Libraries*, **33** (2) 61 (Feb. 1942). Science-Technology Group of the S.L. Assoc., New York, is compiling a list of U.S.A. holdings of Russian scientific periodicals.

([41]) **Stirling, M. M.**: Library movement in South Africa. II. Since the Bloemfontein Conference. *S.Afr.Libr.*, **1** (1) 36 (Jul. 1933).

([41a]) *Technical Book Review Index.* New York: Special Libraries Association **1** (Sept. 1935)+

([41b]) *Times Literary Supplement*, p. 54 (30 Jan. 1943).

([42]) Union of South Africa. Import Restrictions. From Canada (*G.N.* 703, 9 Apr. 1943); from the U.S.A. (*G.N.* 704, 9 Apr. 1943); from the U.K. (*G.N.* 1011, 28 May 1943).

([43]) Ibid, Report of the Interdepartmental Committee on the libraries of the Union, *etc.* Cape Town: Cape Times, p. 23 1937.

([43a]) Ibid, p. 21.

([44]) Ibid, Report of the University Commission. (*U.G.* 33-1928, para. 55, p. 17 1928.)

([44a]) U.S.A. Postal Regulations (18 Apr. 1942).

([45]) Ibid, Surgeon-General's Office. Index-catalogue of the library, *etc.* Washington: Government Printing Office 1880.

([46]) **Unwin, S.**: Status of books. London: Allen & Unwin [1942?]. Repr. from: *Life and Letters To-day*, **31** (52) 160-69 (Dec. 1941).

([46a]) **Varley, D. H.**: Cape libraries to-day and to-morrow. *S.Afr.Libr.*, **11** (1) 1-8 (Jul. 1943).

([47]) **Webb, B. and S.**: Soviet communism: a new civilisation; 2 ed. p. 953-54, Gollancz 1937.

([47a]) Ibid, p. 920; ([47b]) ibid, p. 891.

(48) WELLS, H. G.: Idea of a world encyclopædia. London: Hogarth 1936. (Day to day pamphlets).

(49) WESSELS, RT. HON. SIR JOHN: Report of the State Library, 1934. Pretoria, p. 11 1935.

(50) World List of scientific periodicals, 1900-33; 2 ed. Oxford: Univ. Press 1934.

## NOTES TO ILLUSTRATE THE GROWTH OF LITERATURE IN CURRENT BIBLIOGRAPHIES.

*Astronomischer Jahresbericht.* From 1,768 items in 1899 to 4,000 in 1936.

*Biological Abstracts.* 50,000 abstracts p.a. from 4,000 to 5,000 periodicals. Of 75,000 articles p.a. the whole number of abstracts is 222,500.

Chemistry. With about 500 periodicals. The abstracting agencies are the oldest (1830+) and more highly developed than in most other subjects, and publications more confined to specific periodicals. *British Chemical Abstracts* (Pure and Applied) survey about 40,000 articles; the American and German equivalents about 70,000.

Economics had six abstracting journals in 1926.

Electrical Engineering is particularly well abstracted; has 400 world-wide journals, with about 25,000 articles p.a. of which 200 good class titles produce about 12,500 correspondingly good articles. Yet the 11 abstracting and indexing periodicals cover only about 2/5 of the articles recorded!

*Engineering Index* (1884+) contains 50,000 articles in 2,000 periodicals published annually in 20 different countries. Has photoprint service for 282 sub-subjects.

*Index Medicus.* From 25,000 items in 1879 to 115,000 items in 1935.

Metallurgy had eight periodicals abstracting 152 journals in 1933, and 200 in 1937, of between 370 and 500 titles, containing 3,500 to 4,500 articles p.a. See: Francis, E. R., Metallurgical literature, its co-ordination and diffusion. *Found. Tr.J.*, **66** (1335-36), 177-79, 194-97, 19 and 26 Mar. 1942.

*Psychological Abstracts.* From 2,730 items in 1927 to 6,063 items in 1937.

*Zoological Record* (1864+) (Insects). From 500 items in 1876 to 3,515 in 1937. Information from Bradford and Hutton above, and from Besterman, T., World bibliography of bibliographies. London: The Author, 1939-40. 2v.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 98-103*
*November, 1943.*

# STUDIES IN STELLAR STATISTICS: III—THE RELATION BETWEEN MASS, LUMINOSITY AND TEMPERATURE

BY

DR. A. E. H. BLEKSLEY,
*University of the Witwatersrand, Johannesburg.*

*Read 28th June, 1943.*

---

1. In earlier papers to the Association (Bleksley, 1937, 1942) I have shown that for the Cepheid variables and for the eclipsing binaries with well-determined elements an empirical mass-luminosity-temperature relation can be derived which is identical with a theoretical relation derived by Dr. J. K. E. Halm in an unpublished investigation. If M is the mass, B the absolute bolometric magnitude, and T the effective temperature of the star, a relation exists connecting these three variables, which is of the form

$$\log M = -0{\cdot}12\ B - 0{\cdot}20 \log T \quad . \ . \ . \quad (1)$$

This relation is sufficiently simple to make it particularly useful in application if it possesses general validity, and it appeared worth investigating the relation between these three variables from other sets of data.

2. The first test is provided by the material used by Eddington in testing his theoretical mass-luminosity relation (Eddington, 1930). From the two tables of first- and second-class determinations of the mass of binary systems given by Eddington, and giving a second-class determination one-third of the weight of that attached to one of the first-class, a least-squares solution was made to determine the co-efficients in an equation of the form of (1). The resulting equation was found to be

$$\log M = \underset{\pm\, 0{\cdot}003}{-\ 0{\cdot}117}\ B \ \underset{\pm\, 0{\cdot}07}{-\ 0{\cdot}15} \log T \pm 0{\cdot}022$$

The agreement is complete within the probable errors of the co-efficients. It seems that the co-efficient of log T is not very well determined. Fortunately, however, the variation in temperature is not very considerable, so that an error in the co-efficient has comparatively little effect on the resulting value of M.

This being the case, it might be worth eliminating the temperature completely by assuming that the stars concerned are all members of the main sequence, an assumption which

in the majority of cases will be justified. In this case we have for members of the main stellar sequence a relationship between bolometric absolute magnitude and logarithm of the temperature, equivalent to the Russell-Hertzsprung clustering, which I have shown to be given by a linear relation. For the temperature scale given in a previous publication (Bleksley, 1935 (2) ) I found the relation to be

$$\log T = -0{\cdot}066\ B + 0{\cdot}30 \quad . \quad . \quad . \quad . \quad (2)$$

while for the temperature scale of Brill, I found the relation (Bleksley, 1942)

$$\log T = -0{\cdot}050\ B + \text{constant}.$$

The difference in the co-efficients in these two cases is in all probability due to the difference in the two temperature scales. The difference between the two results is not of importance when the equation (2) is substituted in (1), giving a mass-luminosity relation for the main-sequence of the form

$$\log M = -0{\cdot}11\ B + \text{constant} \quad . \quad . \quad . \quad . \quad (3)$$

In order to illustrate the agreement between these relations and the observations, we give in Table 1 the stars with well-determined masses in Eddington's table, with the observed mass M, the observed bolometric absolute magniture B, the observed temperature T, the value of B calculated from the mass by means of (1), that calculated from (2), and the value calculated from Eddington's mass-luminosity relation.

TABLE 1.

BINARY STARS—FIRST-CLASS DETERMINATIONS.

| Star | Obs. M | Obs. B | Obs. T | Calc. B (1) | Calc. B (2) | Calc. B (Edd.) |
|---|---|---|---|---|---|---|
| Capella *b* | 4·18 | −0·36 | 5200 | −0·21 | −0·65 | −0·34 |
| Capella *f* | 3·32 | 0·22 | 7400 | 0·32 | 0·24 | 0·02 |
| Sirius *b* | 2·45 | 0·97 | 10500 | 1·22 | 1·43 | 0·67 |
| $\alpha$ Cen *b* | 1·14 | 4.53 | 5000 | 4·49 | 4·12 | 4·16 |
| $\alpha$ Cen *f* | 0·97 | 5·24 | 3700 | 5·29 | 5·05 | 5·09 |
| Sun . | 1·00 | 4·85 | 5740 | 4·9 | 4·93 | 4·56 |
| Kr. 60 *b* | 0·27 | 9·82 | 3100 | 10·01 | 10·05 | 11·07 |
| Kr. 60 *f* | 0·16 | 12·32 | 3100 | 11·90 | 12·09 | 13·55 |

The more complete relation (1) gives, as is to be expected, a slightly better representation of the observed magnitudes than the relation (2), the mean square residuals in the two cases being 0·038 and 0·057 respectively. In both cases the agreement can be regarded as good.

3. A more recent compilation of the data of masses and absolute magnitudes in visual binaries is given in a paper by Pilowski (Pilowski 1936). The important data are given in Table 2, in which successive columns give the name of the star,

the logarithm of the effective temperature determined from the spectral type by a table given by Pilowski, the absolute bolometric magnitude, determined from the visual magnitude by means of the bolometric correction (Bleksley, 1935 (1) ), the observed logarithm of the mass and the class of the determination, I being most accurate, III least so.

TABLE 2.

MASSES OF VISUAL BINARIES.

| Name | log T | B | log M | Class |
|---|---|---|---|---|
| Sun . . | 0·00 | 4·85 | 0·00 | I |
| η Cas . | 0·00 | 4·9 | - 0·05 | II |
| | −0·20 · | 7·8 | −0·47 | II |
| $0_2$ Eri BC . . | 0·17 | 10·5 | −0·35 | II |
| | - 0·36 | 10·2 | - 0·70 | II |
| α Aur .. ... | - 0·01 | 0·0 | 0·62 | I |
| | −0·01 | 0·5 | 0·52 | I |
| α C Ma . ... | 0·17 | 1·1 | 0·37 | I |
| | 0·06 | 11·3 | 0·03 | III* |
| α C Mi ... ... | 0·07 | 2·8 | 0·17 | I |
| | 0·07 | 15·8 | −0·34 | III* |
| 9 Arg ... ... | −0·01 | 4·7 | 0·19 | II |
| | −0·01 | 5·3 | 0·10 | II |
| γ Vir ... ... | 0·07 | 3·4 | 0·05 | III |
| | 0·07 | 3·4 | 0·05 | III |
| ζ U Ma . . ... | 0·17 | 1·2 | 0·41 | I |
| | 0·17 | 1·2 | 0·41 | I |
| α Cen ... ... | −0·04 | 4·6 | 0·01 | I |
| | −0·04 | 5·8 | −0·01 | I |
| ξ Boo ... ... | −0·05 | 5·5 | −0·07 | II |
| | −0·14 | 7·3 | −0·12 | II |
| β 416 ... ... | −0·14 | 6·5 | −0·21 | II |
| | −0·14 | 8·5 | −0·31 | II |
| 26 Dra .. ... | −0·01 | 4·4 | −0·01 | III |
| | −0·01 | 9·1 | −0·06 | III |
| 99 Her ... ... | 0·03 | 3·7 | 0·32 | III |
| | 0·03 | 8·2 | −0·01 | III |
| β 648 . . ... | 0·00 | 4·1 | 0·22 | III |
| | 0·00 | 7·5 | −0·04 | III |
| δ Equ ... ... | 0·04 | 4·2 | 0·16 | III |
| | 0·04 | 4·3 | 0·14 | III |
| Kr 60 AB ... ... | −0·33 | 9·6 | −0·66 | II |
| | −0·33 | 10·9 | −0·77 | II |
| 85 Peg ... ... | 0·00 | 5·5 | −0·21 | II |
| | 0·00 | 10·7 | −0·70 | II |
| ADS 520 ... ... | −0·06 | 5·4 | −0·21 | III |
| | −0·06 | 5·7 | −0·21 | III |
| Boss 376/77 ... | −0·05 | 6·8 | 0·11 | III |
| | −0·05 | 6·8 | 0·11 | III |

TABLE 2—continued.

MASSES OF VISUAL BINARIES.

| Name | | log T | B | log M | Class |
|---|---|---|---|---|---|
| ADS 7281 | ... | −0·11 | 6·5 | −0·21 | III |
| | | −0·11 | 6·8 | −0·21 | III |
| ADS 8801 | ... | 0·04 | 4·0 | 0·08 | III |
| | | 0·04 | 4·0 | 0·08 | III |
| ADS 9031 | ... | −0·17 | 6·2 | 0·17 | III |
| | | −0·17 | 6·6 | 0·17 | III |
| ADS 9716 | ... | −0·11 | 5·4 | −0·06 | III |
| | | −0·11 | 5·7 | −0·06 | III |
| ADS 10075 | .. | 0·09 | 6·5 | 0·26 | III |
| | | 0·09 | 6·5 | −0·26 | III |
| ADS 10598 | | −0·05 | 4·4 | 0·35 | III |
| | | −0·05 | 4·7 | 0·35 | III |
| α Her BC ... | .. | −0·31 | 8·6 | −0·35 | II |
| | | 0·31 | 9·1 | −0·35 | II |

In the above table the temperature of the sun was taken as unity. The two objects marked with an asterisk are white dwarfs and have been placed in Class III.

4. The material of the above table was subjected to correlation analysis.

For the material of the Class I a separate analysis was made, leading to the results given in Table 3.

TABLE 3.

CORRELATIONS—FIRST-CLASS DETERMINATIONS.

| Variables. | | Coefficient of Correlation. | | Probable Error. |
|---|---|---|---|---|
| B, log T | ... .. | −0·61 | ... | 0·2 |
| B, log M | .. ... | −0·98 | ... | 0·02 |
| log M, log T | ... | 0·55 | ... | 0·25 |

The only certainly significant relationship is that between B and log M. The regression line for this relationship is given by

$$\log M = -0{\cdot}11\,B + 0{\cdot}55 \quad . \quad . \quad . \quad . \quad (4)$$

5. In discussing the correlations for the entire material, relative weights were attached as follows:—

| | | |
|---|---|---|
| Class I | ... ... | Relative weight 1 |
| Class II | ... ... | Relative weight ½ |
| Class III | ... ... | Relative weight ¼ |

In addition, the two white dwarfs marked * in Table 2 were left out of the discussion. The chief statistical data are given in Table 4, and the correlation co-efficients with their probable errors in Table 5.

TABLE 4.

| Variable. | Mean. | Standard Deviation. | Weight. |
|---|---|---|---|
| B | 5·148 | 3·01 | 23·5 |
| log T | −0·040 | 0·144 | — |
| log M | 0·0064 | 0·345 | — |

TABLE 5.

| Variables | Coefficient of Correlation. | Probable Error. |
|---|---|---|
| B, log T | −0·66 | 0·10 |
| B, log M | −0·91 | 0·05 |
| log M, log T | 0·77 | 0·08 |

There exist, therefore, marked correlations between all three variables, and it is advisable to compute the coefficients of partial correlation in order to separate out the effect of one correlation on another. In the standard notation if ${}_zR_{xy}$ represents the coefficient of partial correlation of x on y with the variable z held constant, we have

$$ {}_zR_{xy} = \frac{R_{xy} - R_{xz} \cdot R_{yz}}{\sqrt{[(1 - R^2_{xz})\,(1 - R^2_{yz})}} $$

Using this formula, we find

$$ {}_B R_{\log M,\, \log T} = 0\cdot55 $$

and

$$ {}_{\log T} R_{\log M,\, B} = -\ 0\cdot73 $$

It therefore follows that the mass is correlated definitely with luminosity and with temperature when the other of these variables is held constant.

The coefficient of multiple correlation for log M on B and log T together is found by the usual methods to be

$$ R_{\log M\ (B,\ \log T)} = 0\cdot94 \pm 0\cdot04 $$

which does not differ significantly from the simple coefficient of correlation of log M on B, namely 0·91. Hence on the present evidence it would appear that in general the accuracy obtained from the simple formula (2) is not significantly less than that obtained by the use of the more complicated relation (1). That is, a mass-luminosity relation gives results as good as a relation connecting mass, luminosity and temperature.

The equation of the " line of best fit " (Bleksley, 1942 (2) ) is found for the mass-luminosity relation to be

$$ \log M = -\ 0\cdot105\ B + 0\cdot55 \quad . \quad . \quad . \quad . \quad (5) $$

which agrees very closely with the regression line (4) found for the first-class determinations and with the general equation (3).

6. From the foregoing it follows that the mass of a star can be determined from a knowledge of its spectral type alone, if no other information is available, by assuming that the star belongs to the main sequence. From the Russell-Hertzsprung diagram it is possible to determine the most probable bolometric absolute magnitude of the star, and hence its mass from the mass-luminosity equation (3). Owing to the small coefficient of $B$ in this relation, the mass is accurately determined even if the star does not lie exactly on the mean line of the main sequence.

## REFERENCES.

BLEKSLEY, A. E. H.: "Studies in Stellar statistics: I." *This Journal*, **32**: 118-124 (1935).

BLEKSLEY, A. E. H.: "The relation between the bolometric magnitudes and the temperatures of the stars." *Ast.Nach.*, **254**: 297-302 (1935).

BLEKSLEY, A. E. H.: "Studies in Stellar statistics II." *This Journal*, **33**: 144-146 (1937).

BLEKSLEY, A. E. H.: "The pulsation variables." *This Journal*, **34**: 135-168 (1937).

BLEKSLEY, A. E. H.: "A statistical study of mass, density, and radius in some eclipsing binaries." *This Journal*, **38**: 133-140 (1942).

BLEKSLEY, A. E. H.: "Note on the straight line of best fit for a set of coplanar points." *This Journal*, **38**: 141-144 (1942).

EDDINGTON, A. S.: "The internal constitution of the stars: Cambridge, 154 (1930).

PILOWSKI, K.: "Die Strahlungstemperaturen für die Hauptreihe des Russell-Diagramms." *Zeits. fur Astrophysik*, **11**: 265-304 (1936).

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 104-108*
*November, 1943.*

# AN ELECTROSTATIC GENERATOR FOR ONE MILLION VOLTS

BY

DR. A. E. H. BLEKSLEY,
*University of the Witwatersrand, Johannesburg.*

*Read 28th June, 1943.*

1. For the generation of high-energy particles for use in nuclear disintegration there are to-day two major tools—the cyclotron and the electrostatic generator of the type developed by Van de Graaff. For general usefulness in nuclear physics there is no doubt that the former is the more valuable, but it possesses certain disadvantages, not the least of which is its comparatively high cost. With a certain programme of research in nuclear physics in view, it was therefore decided that the available funds would not allow of any equipment more ambitious than a Van de Graaff generator to give potentials of the order of one million volts. Since, largely on account of the difficulties of obtaining equipment at the present time, the design adopted has some unusual features, this description of our instrument is given.

2. The normal breakdown gradient in air is given as about 30 kv. per cm. In humid air the value is in general considerably less. Assuming a breakdown gradient of one-half of this value, a sphere of 75 cms. radius will stand a potential of one million volts without breakdown of the air. Hence it was decided that a sphere of this size would be adequate for the purpose, while anything larger would prove difficult to house.

Two hemispheres 5 feet in diameter were accordingly made by rolling sheet iron cut to the correct shape and spot welding the sheets together on the inside. The outside surface was very carefully polished in order to eliminate roughness and irregularities which would tend to cause breakdown at a lower voltage.

The lower hemisphere has a hole 2 feet in diameter cut concentric with the axis of symmetry, the edges of this hole being rolled over into a curve of several inches radius of curvature. The two hemispheres are mounted together by means of countersunk screws, and the charging belt enters the terminal so formed through the hole in the lower hemisphere.

It is at this point that breakdown normally takes place, the potential field being most intense at the edge of the hole and giving rise to sparks to the belt. In order to overcome this difficulty, and to distribute the potential between terminal and

earth in as even a manner as possible, it was decided to use a system of circular grading rings placed parallel to one another so as to enclose the charging belt. The rings are carried on three pillars built of a series of porcelain " stand-off " insulators screwed together, which serve as the support for the high-voltage terminal. The potential distribution along this column of rings is maintained by corona from points on each ring to the next positive ring, in accordance with the recommendations of Van Atta and Nowak (Van Atta and Nowak, 1941).

For current stability—that is, in order that corona current should be independent of voltage over a fairly wide range of the latter—these authors have shown that it is necessary that corona should take place from negative points and that the gaps should be large. Over the greater portion of the column the gaps were chosen to be about 2 inches, the diameter of the rings being about ½ inch. Near the top of the column, i.e. approaching the hole in the sphere, where it is important that the field be removed as completely as possible from the region of the hole, the rings are more closely spaced, being a little over ½ inch apart.

Three sharp points project from each ring toward the next ring on the positive side, i.e. upwards in most applications of the generator, and provide at a terminal potential of one million volts a corona current which, from Van Atta and Nowak, will be in the neighbourhood of one hundred microamperes.

The total height of the insulating columns as at present available is about 54 inches. The total number of corona rings is about 30, and the calculated breakdown voltage of the column is about 1,100 kilovolts. The height of the column is at present determined at this low value by the comparatively low wall-height of the laboratory in which the instrument has been set up. If a room with some feet more headroom were available, it would be possible to increase the length of the supporting column and so increase the maximum attainable voltage.

The insulators used for the supporting columns were ordinary porcelain cylindrical insulators, corrugated on the outside, with a breakdown strength of about 25 kv./inch.

3. Charging Belt System.—In most generators the charging is done by one or more endless belts passing over two parallel pulleys, one mounted in the sphere, the other at ground level. These belts are sprayed with positive charge by means of corona discharge at the lower pulley, and carry this positive charge into the upper terminal, where by a Faraday cage principle the charge is drawn off to the outside of the sphere.

By insulating the upper pulley so that it can become charged to a potential of several thousand volts relative to the sphere, it is possible to spray charge of the opposite sign on to the moving belt after its original charge has been drawn off, so that the

belt carries, say, positive charge up and negative charge down. The charging rate is correspondingly increased.

The amount of charge that can be sprayed on to the belt is determined by the breakdown of the air in its neighbourhood. Normal breakdown potential for air is reached with a charge of $2 \cdot 7 \times 10^{-9}$ coulombs per sq. cm. A belt of width 20 inches made of rubber sheeting such as is used in hospitals with the join vulcanised is driven on two parallel pulleys of 4in. diameter running at about 3,600 revolutions per minute. Such a belt, carrying away negative charge from the sphere as well as positive charge to it, will provide a maximum charging current of about 500 microamperes. In practice it is doubtful whether, in view of the general experience with charging belts, more than about 60 per cent. of this current will be obtained. For the investigation in view this should, however, prove to be a sufficiently large current, since in nuclear investigations it is rare that ion currents amounting to as much as 100 microamps. are used.

The upper collector consists of a pulley insulated from the sphere by means of rubber cushions, which provide a certain amount of insulation from mechanical vibration as well. Just below the point of tangency of the rising belt, a brass rod fitted with gramophone needles about ½ inch apart and slightly less than ½ inch long, electrically attached to the pulley, draws by corona the charge from the ascending belt and charges the pulley to a potential of some thousands of volts. A further row of corona points insulated from the pulley but connected to the sphere is placed just above the pulley. This collects positive charge and charges the belt negatively. It is at present doubtful whether the upward and downward currents are very well equalised.

The positive charge is sprayed on to the belt by means of a row of corona points opposite the lower pulley, the potential being supplied at present by an X-ray transformer and rectifier of unnecessary capacity, which is, however, being used for want of a more suitable source of low-current high-potential such as is needed for the purpose. It is found that the sphere becomes charged by a process of self-excitation if the belt is driven without any spray potential, but this phenomenon appears to be very erratic, and is certainly not sufficiently reliable to render the transformer-rectifier unnecessary.

4. On account of the small clearance of about 30 inches between the top of the sphere and the ceiling of the laboratory in which the generator was erected, and of the danger of sparking from the terminal to the ceiling, no attempt has yet been made to determine the maximum available potential. It is thought that with adequate shielding voltages up to about half a million should be obtainable without spark-over. It is, however, hoped that a laboratory with more head-room will become available,

in which case the maximum voltage will be correspondingly raised. At various stages of the erection of the apparatus alterations have suggested themselves, and these changes will be introduced before the instrument is finally set up.

In the first instance, it is intended that the instrument be used to accelerate protons in order to bombard the lighter elements and to determine cross-sections for various energies of the bombarding particles. This information is of very considerable astrophysical importance on account of the likelihood that these reactions are responsible for the generation of stellar energy.

In spite of the war, the cost of the generator itself, apart from such accessories as vacuum pumps, discharge tube, ion source and the like has proved to be extremely low. It would seem that for many other fields of investigation an electrostatic generator of this type should prove to be an inexpensive and extremely convenient source of high potential.

The generator could not have been built without the assistance willingly given by many people. For help in designing and building the instrument I am particularly indebted to Mr. A. Goldsmith and Mr. C. Buckland, of the University of the Witwatersrand; to Mr. F. Hughes, of Messrs. B. Owen Jones & Co.; and to Mr. H. Greenish, of Greenish & Basterfield. I would also wish to express my gratitude to the National Research Council and Board for a research grant which made the project possible.

## Summary.

An electrostatic generator of the Van de Graaff type with some unusual features is described. The high voltage terminal is a sphere of diameter 5 feet, mounted on porcelain stand-off insulators. The charging belt has a width of 20 inches and moves at 3,600 feet per minute, providing a charging current of about one-half milliampere. The field is distributed about the insulating column and the charging belt by means of a system of grading rings, which prevent discharge from the sphere to the belt. The maximum attainable potential in the present position is about one-half megavolt, the potential being limited by the low ceiling. In a room with some feet more wall-height a voltage of over a million volts should be reached.

The instrument is to be used in the first instance for nuclear bombardment with protons. It is intended to investigate particularly the cross-sections for various proton reactions with the lighter elements as functions of energy of the bombarding particles, with special reference to the problem of the generation of stellar energy.

## REFERENCES.

Bennett, W. H.: "Belt-type generator with small vertical clearance." *Rev.Sci.Inst.*, **7**: 53-54 (1936).

Bramhall, E. H.: "A Portable high-voltage generator of practical utility." *Rev.Sci.Inst.*, **5**: 18-23 (1934).

COLLINS, G. B., WALDMAN, B. and GUTH, E.: "Disintegration of Beryllium by electrons.,, *Phys.Rev.*, **56:** 876-880 (1939).

GETTING, I. A., FISK, J. B. and VOGT, H. G.: "Some features of an electrostatic generator and ion source for high voltage research." *Phys.Rev.*, **56:** 1098-1104 (1939).

LAURITSEN, T., LAURITSEN, C. C. and FOWLER, W. A.: "Application of a pressure electrostatic generator to the transmutation of light elements by protons." *Phys.Rev.*, **59:** 241-253 (1941).

SCOTT, G. W., JNR. and HASKINS, C. P.: "Design and performance of a proton accelerator for quantitative irradiation of living matter." *Rev.Sci.Inst.*, **12:** 466-471 (1941).

TRUMP, J. G., MERRILL, F. H. and SAFFORD, F. J.: "Van de Graaff generator for general laboratory use." *Rev.Sci.Inst.*, **9:** 398-403 (1938).

ATTA, L. C. VAN and NOWAK, W. B.: "Use of corona gaps in high voltage work." *Rev.Sci.Inst.*, **12:** 305-308 (1941).

South African Journal of Science, *Vol. XL, pp. 109-112*
*November, 1943.*

# THE CONDITIONS OF DEPOSITION OF THE FIRECLAYS AT BOKSBURG, TRANSVAAL.

BY

V. L. Bosazza,
*University of the Witwatersrand.*

*With Text-figure.*

*Read 28th June, 1943.*

All the fireclays in the Transvaal are Upper Dwyka to Ecca in age and occur in one of the following positions:—

(a) In shallow basins and drainage systems on the Dolomite Series or on the Witwatersrand System.

(b) In sink-holes in the Dolomite, these being of two sub-types—

1. Hard non-plastic flint clays.
2. Chocolate-coloured semi-refractory and refractory fireclays high in colloid content.

In this paper the origin of occurrence (a) only is discussed, as many aspects of these deposits are not clear and the simplest case must be considered first. Another important point is that, other than in the exploited deposits, exposures are so poor that little can be seen, though, as the clay-faces advance, new features are disclosed. The field-work from which these deductions are made was done in 1938 and 1939.

## Fireclays Occurring in Shallow Basins and Ancient Drainage Areas.

The best exposed deposits, which have almost become classical, are exposed just east of Boksburg, mainly on the farm Kliptontein. Any clear picture of their genesis is rendered difficult by the following anomalies:

1. The presence beneath and close to the clays—often as little as a few inches, but more often not more than a few feet away—of the Dwyka conglomerate, grits, sandstones and arkoses, indicating a fairly high current velocity, some of those materials having obviously been dropped from melting ice.

2. The fine grain of the fireclay, indicating settlement in calm, shallow water, or either turbulent or calm deep water.

3. The absence of ripple marking and the fact that the associated grits and conglomerate are so badly sorted, implying glacial depositon and shallow stream-flow in the summer months.

The highly angular character of the sand grains indicates a near source of the parent rock.

For details reference should be made to an earlier paper (Bosazza, 1941) on the clays of the Witwatersrand area (2) (3). How can all these factors be reconciled? About four to five years ago I discussed the problem with Dr. A. L. du Toit. He suggested that I study the geology of Northern Russia. Recently I read P. P. Shirshov's chapter "Living Creatures of the Polar Seas" in "The Voyage of the Chelyuskin" (1) and this sheds much light on conditions below the ice floes as well as on the vegetable and animal life in those seas. I have also been able to make some observations on the coagulation of the colloidal matter in Nile water and its deposition in Lake Timsah, and it appears that at depths of ten to twenty metres and even less, such fine grained matter can deposit quite easily if the water is saline. If it is not saline, wave action and thermal currents can keep the fine grained matter, say from 50 microns downwards, in suspension. As theorising might seem premature, in view of the small amount of data available on recent deposition, this paper is written mainly to stimulate interest and criticism. As Prof. R. B. Young used to say, "sedimentary rocks have such a 'human' tale to tell," that he could not understand the great interest taken in this country in igneous rocks. It is a fact that, with the exception of general regional geology and the work of Dr. Young, there has been little research on sediments in South Africa.

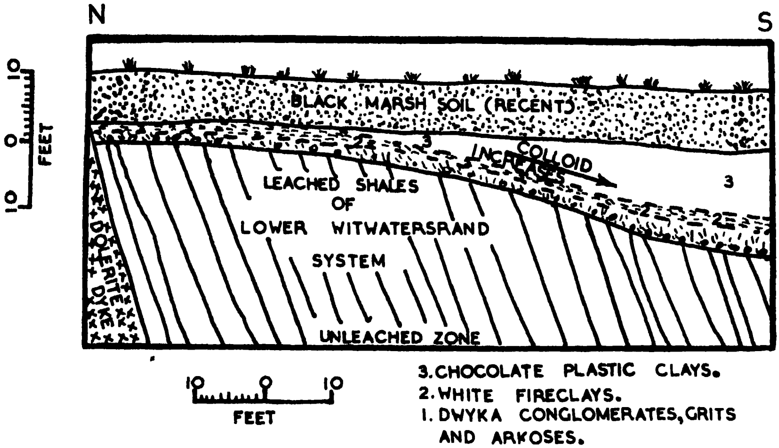



FIG. I.

In Fig. 1 a section in the quarry of the Union Fireclay Coy. is shown. The "telescoping" of the parent rock of the fireclays (the leached Witwatersrand Shales), the Dwyka conglomerate and the fireclays will be noted; also the small total thickness of strata, although subsequent denudation may have

removed some material. That does not affect the close relationship of the underlying rocks.

Now the ice flow preceding the deposition of the Karroo strata was generally southwards, and shallow-water conditions in deltas or lagoons, somewhat similar to the Nile delta and lagoons along the Western Desert may be assumed. The conditions are analogous in the northern plains of the coastal region of Russia. The presence of ice floes and floating blocks, broken from glaciers, reduces wave action, the quiet shallow water below the ice being comparable to much deeper water where exposed to wind action. It is not very difficult to see how colloids carried down by water flowing under the glaciers or by rivers in summer would deposit in contact with salt water. The origin of the highly aluminous colloids can be ascribed to the leaching of the Witwatersrand shales as well as of the granite to the north of these deposits. A similar mechanism has been described by Frankel and Kent in their paper on the Grahamstown surface quartzites, where white clays have been formed under intense leaching. Much research remains to be done on the exact process, but this does not affect the general argument. It is more a matter of the physico-chemical composition of the colloidal system during deposition, that is to say its dispersion and its coagulation.

The boulders of the Dwyka conglomerate could have been transported entirely by ice action. Dr. du Toit pointed out several undoubted cases of this. The arkoses, however, with their content of kaolin must have been deposited simultaneously in water from some stream. It is difficult to visualise how else the gritty and semi-colloidal and colloidal particles could have become associated.

Following on the formation of the Dwyka and the coarse sand rocks, colloidal deposition predominated and the climate gradually became warmer until the formation of coal in shallow lagoons and marshes took place. Although I have not fixed the exact position of the coal horizon, owing to poor exposures, it is not more than two hundred feet above this and certainly much less in most places in this neighbourhood.

The organic matter ([3]) in the fireclays can be ascribed to planktonic remains deposited on the shallow bottom. Shirshov's quantitative work is interesting. He estimates that at the present time in Polar Seas, photosynthesis can take place to a depth of twenty metres. From my laboratory work on the coagulation curves of fireclays ([4]), it appears to be reasonable to assume this figure for the deepest water during their deposition. My observations on coagulation in the Nile waters, where the Ismailiah Sweet Water Canal enters the highly saline waters of Lake Timsah, also tend to show that such material can be deposited in very shallow water. From his numerous measurements, Shirshov tentatively submitted that during the summer one hectare of the Polar sea could produce from 2 to 2·7 metric tons of dry organic matter. Now the amount of organic matter

in these fireclays rarely exceeds a few per cent. and is usually very much less, so that I can see no difficulty in accounting for its origin in this way. An important point is that no recognisable remains of animal or vegetable life can be seen in the many sections cut. The whole mass appears to be a macerated brown waxy translucent material dispersed evenly throughout the clay, and probably adsorbed in the clay colloid (3).

The shallow estuarine or inshore conditions gave way to sub-tropical and eventually tropical marshes, and led to the forming of coal, as found to the south of the Main Reef Road. Unfortunately the old colliery cannot now be entered so that the passage into the coal cannot well be traced.


## SUMMARY

It is suggested that the fireclays at Boksburg East were deposited under arctic conditions in shallow marshes and close inshore in a shallow sea. The depth of water did not exceed about sixty feet and on the average was probably much less. The various anomalies are then less inconsistent. The removal of the salt from the clays took place before and during the formation of coal, the sea bottom having meanwhile risen somewhat both by deposition and possibly by a general upward movement of the land.


## REFERENCES.


(1) "*The Voyage of the Chelyuskin*," by Members of the Expedition. Chatto and Windus (1935).

(2) BOSAZZA, V. L.: "The Clays of the Witwatersrand Area and Environs." *Memoir* No. 2. Minerals Research Laboratory, University of the Witwatersrand (1941).

(3) BOSAZZA, V. L.: "The Occurrence of Waxlike substances in Fireclays."*Nature*, **144:** 835 (1939).

(4) BOSAZZA, V. L.: "The Coagulation Curves of some Fireclays." *Trans.Brit.Ceram.Soc.*, **39:** 37-40 (1940).

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 113-122*
*November, 1943.*

# CYTOLOGICAL STUDIES IN GENERA OF THE PROTEACEAE

BY

MIRIAM P. DE VOS,
*University of Stellenbosch.*

*With 35 Text-figures.*

*Read 28th June, 1943.*

The only cytological investigations which have hitherto been made in the Proteaceae were carried out by Ballantine (1909) in *Protea lepidocarpon*, and by Brough (1933) and Kausik (1938) in the Australian species *Grevillea robusta*. The present investigation was therefore undertaken to determine the chromosome morphology in the genera and species of the South African branch of the family, and to establish whether easily recognizable differences exist in the chromosome complements of these plants.

## MATERIAL AND TECHNIQUE.

The material for this investigation was procured from the vicinity of Stellenbosch and from Kirstenbosch. Pollen-mother-cells were used for studying the meiotic divisions. Young inflorescences were picked and were brought to the laboratory immediately, where the anthers were examined by the aceto-carmine method described by Heitz (1926). When a flower was found with p.m. cells undergoing reduction division, the rest of its anthers were fixed. Carnoy's fixative did not give good results. Flemming's strong solution was better, and the 2BE fixative (La Cour, 1931) gave the best results, especially when a higher percentage of acetic acid was added. This fixative was used throughout the investigation. The solutions of Navashin and of Bouin proved unsatisfactory for the p.m. cells.

Sections of anthers, 15 μ thick, were stained with Heidenhain's iron-alum haematoxylin. Differentiation was carried out by means of a 4 per cent. iron-alum solution, and later by a saturated picric acid solution (La Cour, 1937). The latter was found to be excellent, as the cytoplasm was rendered more transparent and the chromosomes therefore more distinct.

Gentian violet as a chromosome stain (La Cour, 1931, 1937) proved unsatisfactory, because a clear differentiation between cytoplasm and chromosome could not be obtained. The cytoplasm retained a large amount of the stain, and this happened when using gentian violet made by Grübler, Merck and the B.D.H. Different methods of applying the stain were tried, e.g. gentian violet with iodine (La Cour, 1931), the method of

precipitating the stain in the chromosomes by means of a saturated picric acid solution (La Cour, 1937), and the Gram method of dissolving the gentian violet in aniline water (Chamberlain, 1932). But none of these gave good results.

Smear preparations of p.m. cells failed, because the cells were very dry and did not adhere to the slides long enough to allow the use of haematoxylin as a stain. No improvement was noticed when using Mayer's albumen adhesive.

Root tips obtained from seedlings were used for investigating mitotic divisions. They were fixed in 2BE, Navashin's fluid or Flemming's strong fluid, all of which gave good results. Gentian violet with iodine and iron-alum haematoxylin were both satisfactory. When fruits were unobtainable or when no germination took place, mitotic divisions were studied in growing points of stems and in some cases in young growing ovules.

The figures were drawn with the aid of a Leitz Panphot, giving a magnification of 2,000.

## INVESTIGATION—MEIOSIS.

*Protea.*—Reduction division was studied in the p.m. cells of the following species:—

*P. lanceolata*, E. Mey. (Figs. 1, 2).
*P. obtusifolia*, Buek. (Fig. 3).
*P. scolymocephala*, Reich.
*P. neriifolia*, R. Br. (Fig. 4).
*P. barbigera*, Meisn.
*P. mellifera*, Thunb. (Fig. 5).
*P. grandiceps*, Tratt. (Figs. 6, 7).
*P. grandiflora*, Thunb. (Figs. 8, 9).

The haploid chromosome number in these species was found to be 12. In the first meiotic division 12 pairs of chromosomes occur on the metaphase plates. They are small, nearly circular in outline and uniform in size. When the disjunction of the chromosomes begins to take place, some of the pairs show a constriction in the centre, this being most evident in preparations stained with aceto-carmine.

In diakinetic stages the contracted chromosomes are arranged in pairs, the nucleolus and nuclear membrane still being visible. In *P. grandiceps* (Fig. 6) some of the paired chromosomes show terminalization of chiasmata, the members of the pair then being associated at their ends only. In the anaphase some chromosomes pass to the poles slightly in advance of others (Fig. 2), but lagging chromosomes were not seen. Interphase is a resting stage, the nuclei possessing distinct nuclear membranes.

The second division metaphases invariably showed 12 single chromosomes on the equatorial plates, smaller in size than the bivalent chromosomes in the first division. The spindles in the second division are usually arranged at right angles to each other. A few cases were seen where the two spindles were approximately parallel (Fig. 9).

Leucospermum.—The following species were examined:—

*L. conocarpum*, R. Br. (Figs. 10, 12).
*L. attenuatum*, R. Br. (No permanent mounts).
*L. nutans*, R. Br. (Fig. 11).
*L. reflexum*, Buek.

The haploid chromosome number is 12, the chromosomes being, like those in the species of *Protea*, uniform in size and shape. On the other hand, the p.m. cells undergoing reduction division are larger than those of the species of *Protea*.

In *L. conocarpum* early prophasic stages were found with the uncontracted chromosomes arranged in pairs. Later the members of a pair twist round each other and contract. Twelve bivalents were seen in the metaphase of the first division and 12 single chromosomes on the metaphase plates of the second division, these chromosomes being circular or slightly oval in outline. The interphase is long, a nuclear membrane and nucleoli being differentiated. In the anaphase some chromosomes travel to the poles slightly in advance of the others.

In *L. conocarpum* a slight irregularity in the reduction division sometimes takes place, because three young pollen grains instead of four are present in some old p.m. cells

Mimetes.—In *M. lyrigera* Knight (Fig. 21) the haploid chromosome number is 12. The chromosomes are slightly more oval in outline than those in species of *Protea* and *Leucospermum*. They are uniform in size and very small

Paranomus.—*P. spicatus* O. Kze. (Fig. 19) has 12 chromosomes on the second division metaphase plates, this being the haploid number for the species. The chromosomes are slightly smaller than those in species of *Protea* and *Leucospermum*.

Serruria.—In *S. artemisiaefolia* Knight (Fig. 20) the haploid chromosome number is 12, the chromosomes being small, nearly circular in outline and uniform in size and shape.

Aulax.—*A. pinifolia* Berg. (Figs. 13, 14).
*A. cneorifolia* Knight. (Figs. 15, 16).
*A. pallasia* Stapf. (Figs. 17, 18).

These species possess 11 chromosomes in the haploid generation of the male plants. Reduction division in female plants was not investigated. The 11 bivalent chromosomes on the first metaphase plates and 11 single chromosomes on the second equatorial plates are small and slightly oval in outline. The two spindles in the second division are usually approximately parallel to each other. In *A. pinifolia* terminalization of chiasmata takes place in some chromosomes in diakinesis (Fig. 13).

Brabeium.—In *B. stellatifolium*, Linn. (Fig. 22) the investigation was carried out by means of temporary aceto-carmine smears. The haploid chromosome number was found to be 14, as seen in the metaphases of the first and second reduction divisions. The chromosomes are small and differ slightly in size.

## Mitosis.

The investigation of somatic cell divisions showed the following results:—

| Species. | Region of cell division. | Chomosome numbers (2n). | Figs. |
|---|---|---|---|
| *Protea marginata* ... | Root tip ... ... ... | 24 | 24 |
| *P. cynaroides* ... ... | „ „ ... ... ... | 24 | 26, 27 |
| *P. lanceolata* ... ... | „ „ ... ... ... | 24 | 25 |
| *P. grandiflora* ... .. | „ „ ... ... ... | 24 | 28 |
| *P. obtusifolia* ... ... | „ „ ... ... ... | 24 | 23 |
| *P. mellifera* ... ... | Integuments and nucellus of ovule ... ... | 24 | 29 |
| *Leucospermum conocarpum* | Growing points of stem | 24 | 30 |
| *Leucadendron plumosum* | Root tip ... ... ... | 26 | 31 |
| *L. argenteum* ... ... | „ „ ... ... ... | 24-28? | — |
| *Aulax pinifolia* ... ... | „ „ ... ... ... | 22 | 32 |
| *Brabeium stellatifolium* .. | Root tip and growing point of stem ... | 28 | 33 |

Metaphase stages show that the chromosomes are rod-shaped, some being straight, others bent. In several dividing cells of a plant different numbers of chromosomes were found to be bent, sometimes as many as 18. This indicates that these chromosomes may possess median or nearly median centromeres. The position of the centromere in the straight chromosomes could not be determined. In prophasic stages of *Leucadendron plumosum* median and submedian centromeres, each indicated by a small unstained space, were also seen in some of the chromosomes. Anaphase stages in *Protea cynaroides* showed that some chromosomes possessed median or submedian centromeres, while a few were found probably having terminal or subterminal centromeres (Fig. 26). Some chromosomes in this figure, however, may have been cut by the microtome knife.

While no interspecific differences could be seen in the chromosome complements of different species of one genus, slight intergeneric differences were observed. The chromosomes of *Leucadendron plumosum* and of *Aulax pinifolia* are smaller than those of species of *Protea*, and most of them are straight. They are not uniform in size, a few larger and one or two smaller ones being usually present.

In *Leucadendron argenteum* it was impossible to determine the exact number of chromosomes on the metaphase plates. The number probably lies between 24 and 28, 26 and 28 chromosomes occurring most frequently. These chromosomes are of different sizes.

In *Protea lanceolata* (Fig 25), *P. grandiflora* (Fig. 28), and *P. cynaroides* a small extra fragment occurs at the end of one of the chromosomes in some of the dividing cells of the root tip.

Whether it was attached to a chromosome, could not be determined. Such a fragment might have been caused by the microtome knife passing twice through the middle of a chromosome. On the other hand it may be present in all the cells, being attached to one of the chromosomes in such a way that it could not be identified.

### Post-meiotic Mitosis.

After the reduction division the young pollen grains are set free from the old p.m.c. wall and rest for a while. When the next mitotic division takes place the walls of the young pollen grains are already in such a condition that fixatives cannot penetrate easily. They become too deeply stained with gentian violet and with haematoxylin. Good permanent mounts could therefore not be prepared, and only aceto-carmine preparations were examined. The metaphase chromosomes are usually situated in the centre of the pollen grain. In *Brabeium stellatifolium* 14 chromosomes were observed (Fig. 34), and 12 were seen in *Protea lanceolata* (Fig. 35). They are rod-shaped like the somatic chromosomes, and vary slightly in size. Some are straight, others, especially those situated at the edges of the equatorial plates, are bent, being U- or V-shaped. In these the centromere is median or submedian. The number of bent chromosomes vary in different pollen grains: in *Brabeium stellatifolium* as many as nine bent chromosomes sometimes occur, and in some grains of *Protea lanceolata* 11 out of the 12 chromosomes may be bent.

### Discussion.

The basic chromosome number for the South African genera of Proteaceae probably is 12. The species of *Protea*, *Leucospermum*, *Serruria*, *Mimetes* and *Paranomus* which were investigated, show this haploid chromosome number. Ballantine found that *Protea lepidocarpon* also had 12 chromosomes in the haploid generation. The other genera studied have slightly divergent numbers: in three species of *Aulax* (male plants), n = 11; *Leucadendron plumosum* has 2n = 26; and *Brabeium*, a monotypic genus more nearly related to some Australian Proteaceae, has n = 14. This, however, shows no similarity to the Australian species studied by Brough (1933) and by Kausik (1938). They found *Grevillea robusta* to possess 10 chromosomes in the haploid generation.

Aneuploid relations therefore exist between some genera, and the family corresponds to the Antirrhinum type (Tischler, 1928) or to the descending and ascending types (Wanscher, 1934). According to the latter these types usually show intergeneric relationships, rarely interspecific or intraspecific. This has also been found to be true in the present investigation: identical chromosome numbers occur within the genus (cf. *Protea*, *Leucospermum* and *Aulax*). Interspecific differences must therefore be brought about solely by differences in the structure of the chromosomes.

No polyploid species or genera were found among the plants studied, and it is probable that polyploidy does not occur in the South African genera of the family, as greatly divergent types, ranging from very small shrubs to large trees were examined. Even *Protea cynaroides* which might be expected to be a polyploid, has only 24 chromosomes for its diploid number.

On account of the very small size of the chromosomes, their structure and morphology could not be determined. In the metaphases of the reduction division all the chromosomes in the complement are uniform or nearly uniform in size and shape, but in the late diakinesis slight differences between individual chromosomes occur, some pairs being joined at one or both ends (V- or O-shaped) and some in the centre (X-shaped). This shows that terminalization of chiasmata has taken place in the former cases, while no terminalization has occurred in the latter case (Darlington, 1937). In the anaphase of the first meiotic division the separation of the chromosomes does not start simultaneously and some chromosomes are observed to be slightly in advance of the others. This may be accounted for by the fact that terminalization has taken place in some chromosomes. They would begin to separate before the others (Darlington, 1937). Chromosomes definitely lagging on the equatorial plates, however, have not been found in any of the species studied.

The somatic chromosomes seen in the mitoses are rod-shaped, and differ slightly in size and shape from one another. Some are apparently longer than others of the same complement, but this difference is too slight to allow one to recognize individual chromosomes. Usually a number of chromosomes in a cell are bent, and in these the centromere is probably median or submedian. Other chromosomes are straight, and here the position of the centromere is not evident. Probably a few chromosomes possess terminal or subterminal centromeres (Fig. 26).

In the metaphases and the interphases of the first and second reduction divisions a densely granular zone is seen in the cytoplasm surrounding the chromosomes. Such a zone has also been recorded by Castetter (1926), Cooper (1935) and Stokes (1938). The latter only mentions that the cytoplasm surrounding the spindle contains many granules, but Castetter suggests that this band of densely granular material is doubtless a product of disintegration of the spindle. In all these investigations, including the present, anthers were sectioned and then stained with haematoxylin. These granules may possibly be chondriosomes present in the cytoplasm.

The presence of sex chromosomes was not observed in the meiosis of the male plants of the species of *Aulax* investigated. In the second reduction division both metaphase plates of a cell possess 11 chromosomes. This definitely excludes the possibility of an XO type of sex chromosome existing. Sex chromosomes of the XY type may however be present, the X and Y chromosomes differing so slightly that they could not be identified. No probable sex chromosomes were observed in the mitotic divisions

of the species of *Aulax* and *Leucadendron* studied, although the chromosomes in the complements are not uniform in size, a few large and some smaller ones being present.

## SUMMARY.


1. Meiotic divisions in the pollen-mother-cells in a number of genera show that the basic chromosome number is probably 12. Other genera are aneuploid and have chromosome numbers differing from the basic number by 1 or 2. No polyploidy has been found.

2. These chromosomes are very small, circular or slightly oval in outline, and uniform or almost uniform in size. Terminalization occurs in some chromosomes of the complement.

3. Mitotic divisions showed the diploid number of chromosomes. They are rod-shaped, and in the complements of some genera differences in size and in the position of the centromere occur.

4. Chromosomes in the post-meiotic mitosis in young pollen grains are also rodshaped and are present in the haploid number.


The writer wishes to express her sincere thanks to Prof. G. C. Nel, under whose supervision this investigation took place.

## BIBLIOGRAPHY.


BALLANTINE, A. J.: "A preliminary note on the embryo-sac of Protea lepidocarpon." *Ann.Bot.*, **7:** 161 (1909).

BROUGH, P.: "The life-history of Grevillea robusta." *Proc.Linn. Soc.N.S.Wales*, **58:** 32 (1933).

CASTETTER, E. F.: "Cytological studies in the Cucurbitaceae." *Amer. Journ.Bot.* **13:** 1 (1926).

CHAMBERLAIN, C. J.: "Methods in plant histology." Chicago (1932).

COOPER, G. O.: "Cytological studies in the Chenopodiaceae." *Bot. Gaz.*, **97:** 169 (1935).

DARLINGTON, C. D.: "Recent advances in cytology." (1937).

HEITZ, E.: "Der Nachweis der Chromosomen." *Zeitsch.f.Bot.*, **18:** 625 (1926).

KAUSIK, S. B.: "Studies in the Proteaceae, I. Cytological and floral morphology of Grevillea robusta, Cunn. *Ann.Bot.N.S.*, **2:** 899 (1938).

LA COUR, L.: "Improvements in everyday technique in plant cytology." *Journ.Roy.Micr.Soc.*, **51:** 119 (1931).

LA COUR, L.: "Improvements in plant cytological technique." *Bot. Rev.*, **3:** 241 (1937).

SHARP, L. W.: "Introduction to cytology." New York (1934).

STOKES, J.: "Studies in the Myricaceae." *Bot.Gaz.*, **99:** 387 (1938).

TISCHLER, G.: "Ueber die Verwendung der Chromosomeszahlen für phylogenetische Probleme bei den Angiospermen." *Biol. Zentralbl.*, **48:** 321 (1928).

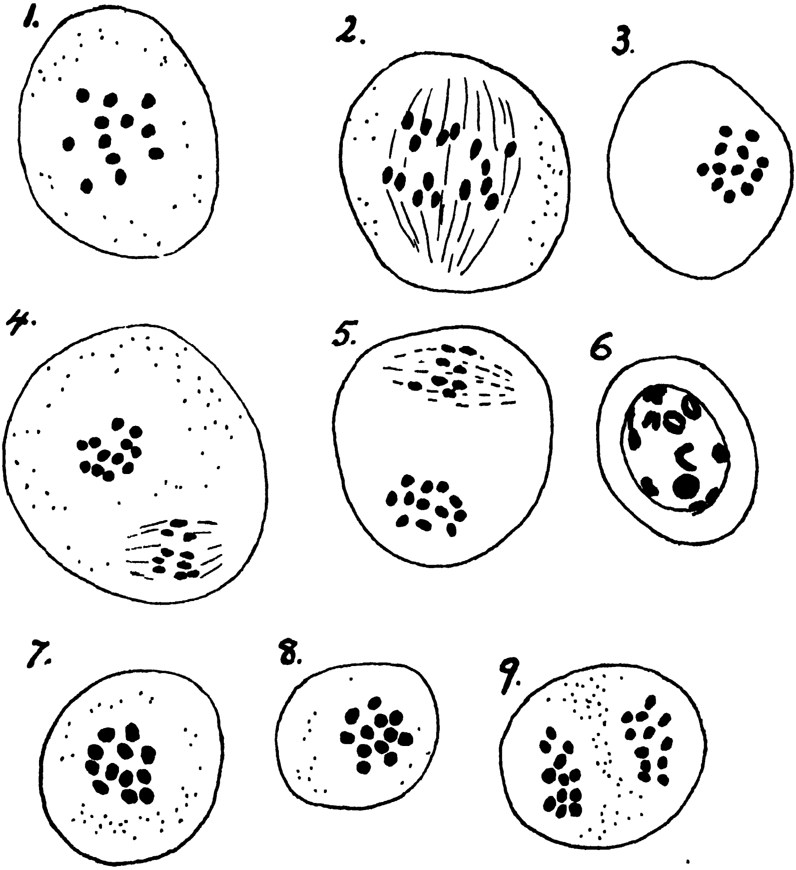
TISCHLER, G.: "Pflanzliche Chromosomen-Zahlen." *Tabulae Biologicae*, **11, 12:** 281 (1935, 1936).

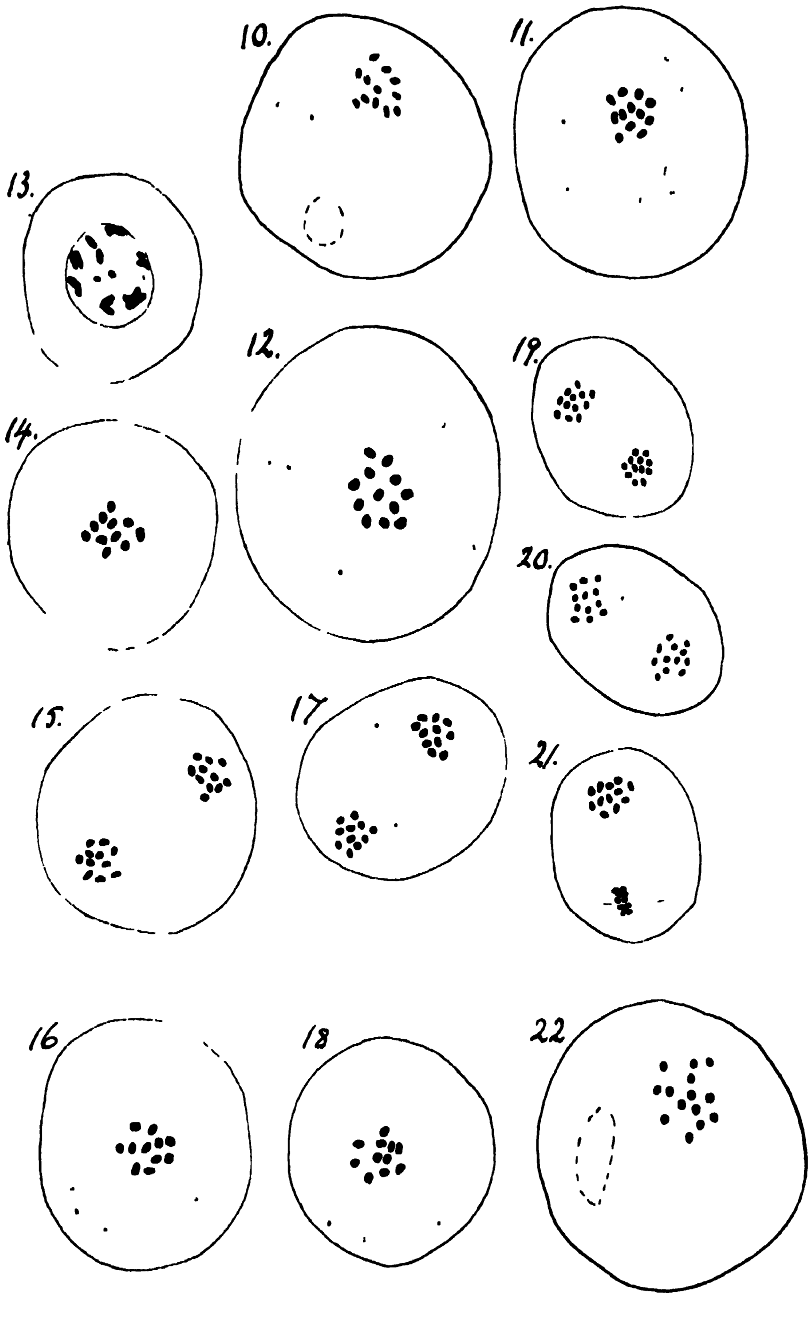
WANSCHER, J. H.: "The basic chromosome number of the higher plants. *New Phyt.*, **33:** 101 (1934).

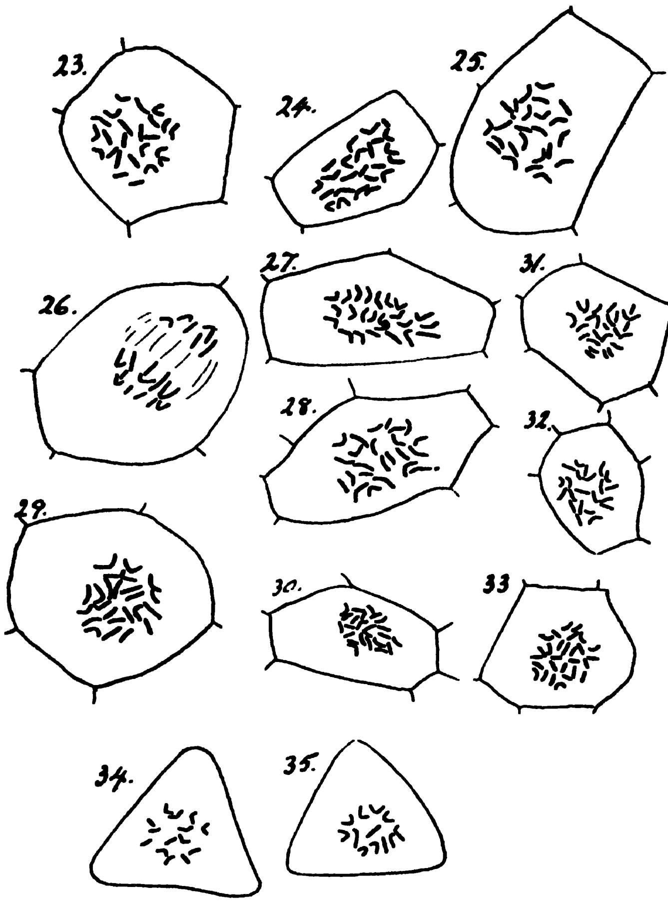

## ILLUSTRATIONS.

Figs.: (1-9) Meiosis in pollen-mother-cells of species of *Protea*: (1) *P. lanceolata*, first metaphase; (2) *P. lanceolata*, first anaphase, not all the chromosomes shown; (3) *P. obtusifolia*, first metaphase;

(4) *P. neriifolia*, second metaphase; (5) *P. mellifera*, second metaphase; (6) *P. grandiceps*, diakinesis, not all the chromosomes shown; (7) *P. grandiceps*, first metaphase; (8) *P. grandiflora*, first metaphase; (9) *P. grandiflora*, second metaphase. (10-22) Meiosis in pollen-mother-cells: (10, 12) *Leucospermum conocarpum*, second and first metaphase; (11) *Leucospermum nutans*, first metaphase; (13) *Aulax pinifolia*, diakinesis not all the chromosomes shown; (14) *Aulax pinifolia*, first metaphase;; (15, 16) *Aulax cneorifolia*, second and first metaphases; (17, 18) *Aulax pallasia*, second and first metaphases; (19) *Paranomus spicatus*, second metaphase; (20) *Serruria artemisiaefolia*, second metaphase; (21) *Mimetes lyrigera*, second metaphase; (22) *Brabeium stellatifolium*, second metaphase, the chromosomes of only one plate shown. (23-33) Mitotic divisions found in root tips, except where otherwise stated: (23) *Protea obtusifolia*, metaphase; (24) *P. marginata*, metaphase; (25) *P. lanceolata*, metaphase; (26) *P. cynaroides*, anaphase, not all the chromosomes shown; (27) *P. cynaroides*, metaphase; (28) *P. grandiflora*, metaphase; (29) *P. mellifera*, metaphase in young ovule; (30) *Leucospermum conocarpum*, metaphase in growing point of stem; (31) *Leucadendron plumosum*, metaphase; (32) *Aulax pinifolia*, metaphase; (33) *Brabeium stellatifolium*, metaphase in growing point of stem; (34) *Brabeium stellatifolium*, metaphase of the post-meiotic mitosis in young pollen grain; (35) *Protea lanceolata*, metaphase of the post-meiotic mitosis in the young pollen grain.




10.
11.
13.
12.
19.
14.
20.
15.
17.
21.
16
18
22


23.
24.
25.
26.
27.
31.
28.
32.
29.
30.
33
34.
35.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 123-126*
*November, 1943.*

# THE GENUS *LACHNOSTYLIS* TURCZ.

BY
DR. R. A. DYER,
*Union Division of Botany and Plant Pathology.*

*With 2 Text-figures.*

*Read 28th June, 1943.*

The genus *Lachnostylis* Turcz. (Euphorbiaceae) was first defined in 1846 by Turczaninow [1] the type species of the generic name being *L. capensis*. Plants agreeing with the generic description, however, had been described earlier under the names *Cluytia hirta* Linn. f. [2] and *C. acuminata* Thunb [3]. Later, other specimens were described by Sonder [4] under the name *Lachnostylis minor*, though he suggested at the time that this might be conspecific with *Cluytia acuminata* Thunb.

When Müller-Argaut [5] revised the genus *Lachnostylis* in 1866, he recognised only one species for which he used the name *L. hirta* (Linn. f.) Mull. Arg., since he correctly identified *L. capensis* Turcz. with the much earlier *Cluytia hirta* Linn. f. At the same time he gave varietal rank to the forms previously described as species under the epithets *acuminata* and *minor*.

The status of these latter was further modified by Hutchinson [6] who merged the two varietal forms described by Mull.-Arg., into a general specific description. Under the "Kew Rule," however, Hutchinson used the name *L. capensis* Turcz., but under International Rules of Botanical Nomenclature [7] this must be replaced by *L. hirta* (Linn. f.) Mull.-Arg., the name correctly used by the latter for the specimens collected by Thunberg in the Cape Province between 1772-75.

Hutchinson's revision of *L. hirta* is accepted here and shows that this species is endemic in the coastal districts of the Cape Province from Port Elizabeth to Swellendam, in which area, too, Thunberg undoubtedly collected the type material.

It is now proposed to include in the genus, under the name *L biloculuris*,* a plant not dealt with by any earlier

---

* *Lachnostylis bilocularis* R. A. Dyer sp. nov. frutex vel arbuscula circiter 3 m. alta. *Folia* breviter petiolata, elliptico-oblonga, 2-3·5 cm. longa, 1-1·8 cm. lata, pilosa, supra glabrescentia. *Stipula* ovata vel lanceolata, 2·3 mm. longa. *Flores* dioeci. *Masc.*: *Sepala* 5, 2·5 mm. longa, 2 mm. lata, pilis appressis pubescentia. *Petala* spathulato-oblonga, 1·5 mm. longa, ciliata. *Discus* 1-1·25 mm. diametro, villosus. *Stamina* 5, libera. *Ovarium* abortivum stylis 2 villosis. *Fem.*: *Sepala* 5, 3·5 mm. longa, 2·5-3 mm. lata leviter accrescentia rotundata, pilis appressis pubescentia. *Petala* oblonga vel lineari-oblonga, 2·5 mm. longa, glabra. *Discus* plus minusve emarginatus, villosus. *Ovarium* biloculare, loculis intra villosis, biovulatis, ovulis pendulis. *Styli* 2, infra pubescentes apice glabri bifidi. *Capsula* pubescens, coccis semine hemispherico ·oun

worker. It differs from *L. hirta* and all its forms, mainly in its 2- (not 3-) locular ovary and in the filaments of the male flowers being free to the base, Fig. 2c (not connate for half their length as in *L. hirta*, Fig.1b). It might be argued that these differences are of generic importance and that *L. bilocularis* should, therefore, not be included in *Lachnostylis*. On the other hand, several genera related to *Lachnostylis* have a variable number of ovary cells (ranging from 1-4) and the filaments in these genera are either partly united or free—both forms being present in the genus *Andrachne L.* Other reasons for associating *Lachnostylis bilocularis* with *L. hirta* are their close similarity in habit and general morphology and their proximate distribution. While *L. hirta* is restricted to coastal bush from Port Elizabeth to Swellendam districts, *L. bilocularis* is apparently endemic further inland on the rocky slopes or krantzes of the Zwartberg, not far distant from the common boundary between the Oudtshoorn and Uniondale districts. The type specimen was collected in May 1941, in Meirings Poort, by Mr. J. D. Keet, formerly Chief of the Division of Forestry. The common name is given as "Klipboom." It is stated to be a "small tree up to 9 feet high, or a many stemmed shrub of about 4-5 feet., growing between rocks on the krantzes of the Zwartberg." The specimen collected in May, 1941, was from a female plant, but later, in January, further material from the same area was obtained, and this included a small twig of a male plant. A previously unnamed specimen in the National Herbarium, Pretoria, collected by Mrs. T. V. Paterson in November, 1912, in the Uniondale division, is conspecific with Mr. Keet's specimen.

It is a pleasure to acknowledge the assistance of officers of the Division of Forestry in supplying material.

The following is an amplified description for the genus *Lachnostylis* to accommodate the species *L. bilocularis*: Plants dioecious, petals present. Male flowers: Sepals 5, subequal, imbricate. Petals 5, membranous, spathulate or obovate, smaller or sometimes slightly longer than the sepals. Disc annular, villous. Stamens 5, free or connate below and forming a short tube. Female flowers: Sepals and petals more or less as in the male flowers. Disc annular, thick, villous. Ovary ovoid-globose, 2-3-locular with 2 ovules in each loculus, tomentose or villous on the outer surface and also pubescent within the loculi; styles 2-3, bifid. Capsule breaking up into 2-valved cocci. Seeds subglobose or hemispherical, smooth or slightly wrinkled; endosperm scanty.

*Lachnostylis bilocularis* R. A. Dyer; shrub or small tree up to about 3m. high, much branched, with the branchlets twiggy with scattered lenticels, tomentose when young, at length glabrous. Leaves petiolate; petiole 3-5 mm. long, shortly pilose; blade elliptic-oblong, obtuse, 2-3·5 cm. long, 1-1·8 cm. broad, very shortly pilose on both surfaces when

young, becoming glabrous on the upper surface with age, minutely reticulately veined on both surfaces (when dry). Stipules ovate to lanceolate, 2-3 mm. long, caducous. Flowers dioecious, grouped in small axillary fascicles towards the tips of branchlets. Pedicels slender, 1-1·2 cm. long, pilose. Male flower: Sepals 2·5 mm. long, 2 mm. broad, adpressed pubescent with more hairs on the outer than on the inner surface. Petals spathulate-oblong, 1·5 mm. long, ciliate. Disc 1-1·25 mm. in diameter, villous. Stamens 5, arising from the centre of the disc; filaments free, about 2·5 mm. long; anthers broadly oblong, with introrse dehiscence. Ovary aborted, with two fan-like villous styles overlapping along the margins. Female flower: Sepals 3·5 mm. long, 2·5-3 mm. broad, accrescent, rounded at the apex, occasionally slightly dentate on the margin, adpressed pubescent, with fewer hairs on the inner concave surface. Petals oblong to linear-oblong, 2·5 mm. long, glabrous. Disc surrounding the base of the ovary, slightly lobed or notched at the insertion of the petals in the young stages, villous. Ovary villous, slightly conical at length subglobose, 2-locular, with 2 ovules in each loculus (only one developing) villous; loculi villous within. Styles 2, comparatively large, about 1 mm. long, bilobed. Capsule subglobose, 5 mm. in diameter; seed rounded on the outer side, flat on the inner face (more or less hemispherical) with surface slightly undulate.

Distribution—Cape Province: Oudtshoorn division; Meirings Poort, May, 1942, Keet in National Herbarium, Pretoria, 27167 (type female), January, 1943, Director of Forestry in National Herbarium, Pretoria, 27168 (type male); 27169 syn-type female; Uniondale division; November, 1912, Paterson, 3018.

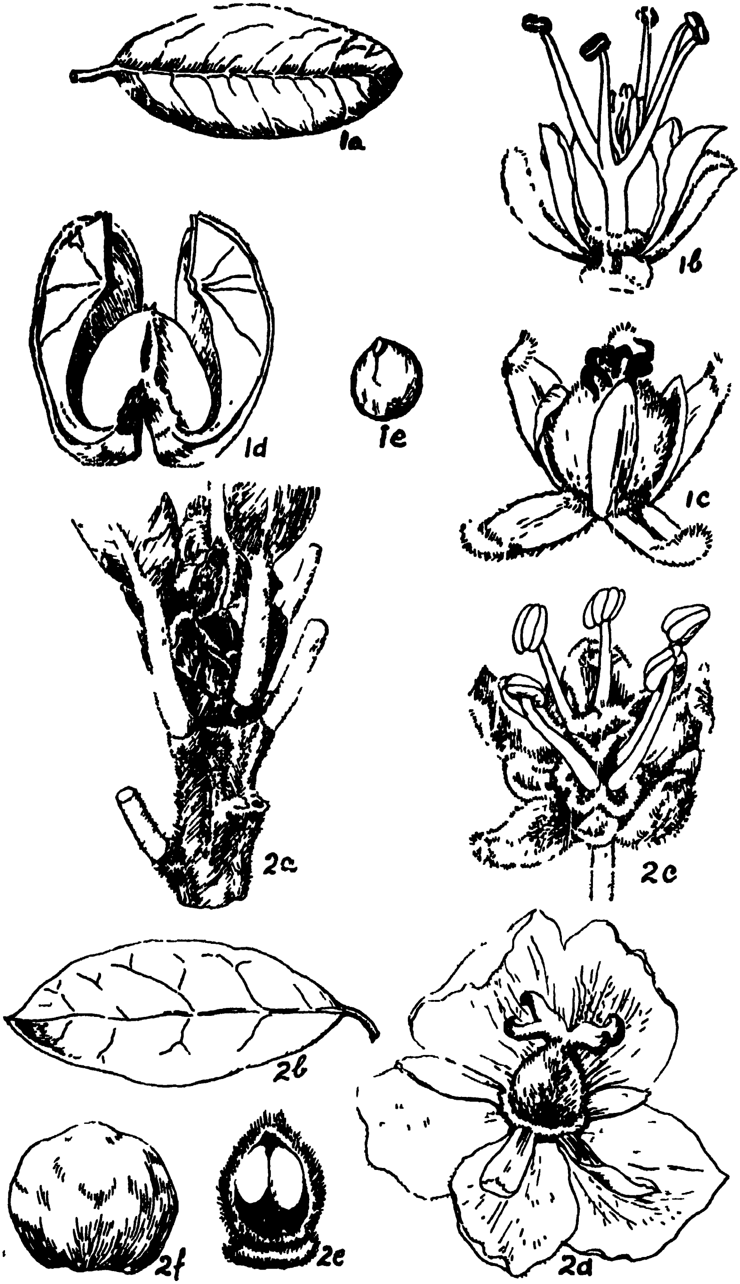
## BIBLIOGRAPHY.


(1) TURCZANINOW: *Bull.Soc.Nat.Mosc.*, **19**: 2, 503 (1846).
(2) LINNAEUS fil.: Supplementum Plant. 432 (1781).
(3) THUNBERG, C. P.: Prodromus Plant. Cap. 53 (1794).
(4) SONDER, W.: *Beitrage Fl. Südafr.* in *Linnaea*, **23**: 132 (1850).
(5) MULLER: De Candolle Prod., **15**: 2, 224 (1866).
(6) HUTCHINSON, J.: in Fl. Cap., **5**: 2, 384 (1915).
(7) International Rules of Bot. Nom. (1935).


## EXPLANATION OF FIGURES.

1a—1e—*Lachnostylis hirta* (*Linn. f.*) *Mull. Arg.*; 1a, leaf; 1b male flower; 1c female flower; 1d, 2-valved coccus; 1e, seed (all enlarged).

2a—2f.—*Lachnostylis bilocularis* R. A. Dyer; 2a, part of twig showing stipules; 2b, leaf; 2c, male flower; 2d, female flower; 2e, ovary showing 2-ovuled loculus; 2f seed back view (all enlarged).


1a
1b
1d
1e
1c
2a
2c
2b
2f
2e
2d

South African Journal of Science, *Vol. XL, pp. 127-134*
*November, 1943.*

# YIELDS AND CHEMICAL COMPOSITION OF PASTURE HERBAGE AS INFLUENCED BY FERTILISING AND FREQUENT CLIPPING.

BY

Dr. H. Weinmann,
*Botanical Department, University of the Witwatersrand, Johannesburg.*

*Read 28th June, 1943.*

The scientific investigation of the South African veld, in particular with regard to its optimal use, has in recent years claimed the attention of a number of workers. The present contribution reports some of the results of a field experiment carried out at Frankenwald, the Botanical Research Station of the University of the Witwatersrand, during the years 1939/40 and 1940/41.

## Experimentation.

Six plots approximately one-sixtieth of an acre in extent were laid out in winter 1939, on a piece of undisturbed veld. The dominant grass species were *Trachypogon plumosus*, *Tristachya hispida*, *Digitaria tricholaenoides*, *Eragrostis chalcantha* and *Brachiaria serrata*. A botanical analysis of the locality has been carried out by M. F. Smith (1940). The soil of the area is an acid loamy sand of about 12in. depth on decomposed granite. The soil is poor in organic matter, nitrogen and phosphorus; the pH was found to be 5·4. The results of a representative analysis of the surface soil are given in Table I. The rainfall amounted to 32·3in. in 1939/40 and to 35·8in. in 1940/41.

TABLE I: RESULTS OF SOIL ANALYSIS.

Percentages of dry fine earth.

| | | | |
|---|---|---|---|
| Sand | 75·2 | Loss on Ignition | 3·9 |
| Silt | 13·0 | Nitrogen | 0·086 |
| Clay | 11·8 | Phosphoric Oxide | 0·016 |
| Total Colloids | 13·4 | Potash | 0·063 |
| Maximum Water Retaining Capacity | 42·4 | | |

In July, 1939, the area which had been subjected to uncontrolled light grazing for some years, was burnt to remove old growth. Three of the above-mentioned six plots were not fertilised (O), whilst the other three plots received a well-balanced fertiliser treatment (PNK) during the two seasons 1939/40 and 1940/41. The amounts of fertiliser applied per morgen during each season were:—

800 lbs. of Kynoch Grass No. 1, equivalent to 120 lbs. $P_2O_5$, 40 lbs. N and 40 lbs. $K_2O$. The fertiliser was spread each

year in spring. Two further dressings of 200 lbs. of ammonium sulphate per morgen (=42 lbs. N per dressing) were applied at convenient intervals during the season.

Five quadrats, each two square metres in extent, were pegged out in each of the six plots. During both seasons these quadrats were subjected to different clipping treatments, as follows:—

NUMBER OF CLIPPINGS PER SEASON.

Quadrat No. 1: One (in the beginning of April).

Quadrat No. 2: Two (in the middle of December and April).

Quadrat No. 3: Four (at two-monthly intervals, namely in November, January, March and May).

Quadrat No. 4: Nine (at monthly intervals from September to May).

Quadrat No. 5: Sixteen (at approximately fortnightly intervals during the months of September to May).

Clipping was carried out with sickles and scissors, the herbage being removed as completely as possible. The herbage was dried in the laboratory at a temperature of 60 to 70°C, and the total herbage yields of the individual quadrats were determined for the whole season. The herbage from the three quadrats receiving the same fertiliser and clipping treament was then combined and ground for chemical analysis. Percentage dry matter, nitrogen, phosphorus, potassium and calcium were determined in the usual way.

## DISCUSSION OF RESULTS.

*Herbage Yields.*—The average herbage yields for the various treatments together with their standard errors are given in Table II.

TABLE II: HERBAGE YIELDS
in grams dry matter per quadrat of two square metres.

| Cuts per season | 1939/40 | | 1940/41 | |
|---|---|---|---|---|
| | O | PNK | O | PNK |
| 1 | 613 ±54 | 696 ±127 | 538 ± 77 | 1,262 ±70 |
| 2 | 587 ±45 | 794 ±103 | 603 ±105 | 1,145 ±77 |
| 4 | 643 ±56 | 817 ± 67 | 505 ± 50 | 1,020 ±19 |
| 9 | 457 ± 8 | 608 ± 43 | 188 ± 37 | 308 ±30 |
| 16 | 352 ±27 | 461 ± 22 | 52 ± 4 | 126 ± 4 |

In both seasons higher average yields were obtained as a result of fertiliser treatment, but whilst in 1939/40 some of

the differences in the yields between fertilised and unfertilised quadrats were not significant, the fertiliser treatment resulted in distinctly higher yields under all conditions of defoliation in the second season. As regards the effect of clipping frequency on the yields, differences in both seasons were relatively small and in most cases statistically insignificant between one, two and four cuts per season. The herbage yields were, however, reduced to a considerable extent by clipping nine times per season and even more so when the grass was cut sixteen times a year. In both the fertilised and unfertilised series this yield reduction was more pronounced in the second season, indicating a cumulative effect. While the fertiliser treatment with one, two and four clippings in the second season gave significantly higher yields than in the first, this effect was completely reversed with nine and sixteen clippings. In fact, with monthly and fortnightly defoliation the yields dropped significantly from the first to the second year of experimentation, irrespective of the fertiliser treatment. On the fortnightly clipped quadrats, growth and regeneration stopped almost completely in the later half of the second season, as most of the plants had apparently been killed by the severe cutting treatment.

*Chemical Composition.*—Table III gives the results of the chemical analyses.

TABLE III CHEMICAL COMPOSITION OF THE HERBAGE

Constituents expressed as percentages of the dry matter.

| Cuts per season | N | | $P_2O_5$ | | $K_2O$ | | CaO | |
|---|---|---|---|---|---|---|---|---|
| | O | PNK | O | PNK | O | PNK | O | PNK |
| 1939/40 | | | | | | | | |
| 1 | 0·80 | 0·79 | 0·19 | 0·24 | 0·87 | 0·94 | 0·37 | 0·38 |
| 2 | 0·81 | 1·01 | 0·23 | 0·30 | 1·39 | 1·58 | 0·43 | 0·43 |
| 4 | 1·01 | 1·17 | 0·25 | 0 30 | 1·73 | 1·64 | 0·39 | 0·42 |
| 9 | 1·40 | 1·45 | 0·44 | 0·41 | 2·02 | 1·89 | 0·35 | 0·35 |
| 16 | 1·60 | 1·73 | 0·49 | 0·45 | 1·67 | 1·88 | 0·43 | 0 37 |
| 1940/41 | | | | | | | | |
| 1 | 0·67 | 0·69 | 0·19 | 0·29 | 0·55 | 1·08 | 0·39 | 0 37 |
| 2 | 0·80 | 0·86 | 0·26 | 0·30 | 0·88 | 1·23 | 0·41 | 0·40 |
| 4 | 1·03 | 1·21 | 0·28 | 0·42 | 1·43 | 1·76 | 0·39 | 0 40 |
| 9 | 1·38 | 1·61 | 0·34 | 0·41 | 1·51 | 1·97 | 0 37 | 0 40 |
| 16 | 1·45 | 1·64 | 0·40 | 0·42 | 1·56 | 1·71 | 0·49 | 0 46 |

The nitrogen, phosphorus and potash content of the herbage was increased by the fertiliser treatment under all conditions of defoliation, except for a few cases during the first year. The influence of the clipping frequency was, however, still more pronounced; the percentages of these three constituents were distinctly raised by shortness of intervals between cuttings, though in some cases maximum values were reached with nine or four clippings per season. The lime content, however, was little affected either by fertilising or frequency of cutting.

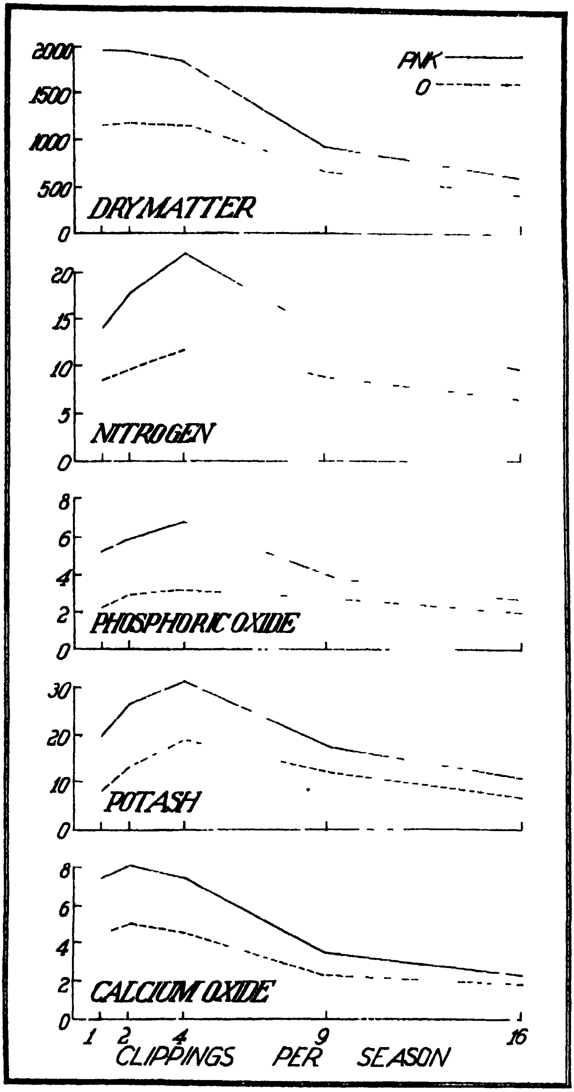
*Total Nutrient Yields.*—From the practical point of view the total yields of nutrients per unit area are, perhaps, more important than the percentage values. The total nutrient yields are shown in Table IV and are also graphically represented together with the total dry matter yields in the Figure.

TABLE IV. TOTAL NUTRIENT YIELDS FOR THE SEASONS 1939/40 AND 1940/41.

In grams per quadrat of two square metres.

| Cuts per season | N | | $P_2O_5$ | | $K_2O$ | | CaO | |
|---|---|---|---|---|---|---|---|---|
| | O | PNK | O | PNK | O | PNK | O | PNK |
| 1 | 8·5 | 14·2 | 2·2 | 5·3 | 8·0 | 20·2 | 4·4 | 7·3 |
| 2 | 9·6 | 17·9 | 2·9 | 5·8 | 13·5 | 26·6 | 5·0 | 8·0 |
| 4 | 11·7 | 21·9 | 3·0 | 6·7 | 18·3 | 31·3 | 4·5 | 7·5 |
| 9 | 9·0 | 13·8 | 2·7 | 3·8 | 12·1 | 17·6 | 2·3 | 3·4 |
| 16 | 6·4 | 10·0 | 1·9 | 2·6 | 6·2 | 10·8 | 1·8 | 2·3 |

As will be seen, the nutrient yields increased with the frequency of clipping up to four cuttings per season which gave maximum amounts of nitrogen, phosphorus and potassium. In the case of calcium the highest amount was present in the herbage harvested twice per season, though the yields from one and four cuttings per year were not appreciably lower. In spite of the higher percentage values of the frequently clipped herbage, the reduction of the dry matter yields with increased frequency of clipping (i.e. nine or sixteen times per season) resulted in corresponding decreases of the nutrient yields. The effect of fertiliser treatment on the nutrient yields was most pronounced with a limited number of clippings, the best results being obtained when the herbage was cut at two-monthly intervals or four times per season. In this clipping treatment the application of fertiliser raised the yield of phosphoric oxide by 124 per cent., of nitrogen by 87 per cent., of potash by 71 per cent. and of lime by 67 per cent. above the level of the unfertilised control.




Total yields of Dry Matter and Nutrients for the seasons 1939/40 and 1940/41. In grams per two square-metres quadrat.

## Conclusions.

The beneficial influence of fertilisers on the yields, chemical composition of the herbage and carrying capacity of this type of veld has been demonstrated by Hall, Meredith and Murray (1937 and 1940) and by Weinmann (1943). Staples and Taylor (1929), Taylor (1931), Du Toit and associates (1935) and Louw (1938) all confirm that frequent cutting at short intervals results in the production of a herbage of superior quality, but they also emphasise the adverse effects of too frequent defoliation on the growth of the plants. The results of the present investigation seem to indicate clearly that severe defoliation at short intervals brings about deleterious effects on the productivity of the pasture, largely counterbalancing the advantage of a better chemical composition of the herbage. Maximum nutrient yields and optimal fertiliser effects can be obtained only with a limited number of harvests per season.

Essentially the same conclusions were reached by the writer in a previous similar investigation (Weinmann, 1943). There it was shown that the decreases in the herbage yields brought about by frequent clipping were associated with corresponding reductions in the root weight of the grasses, and with a depletion of carbohydrate reserves in the roots. In addition, root samples of the five species of grasses named above, were taken at the end of the 1940/41 season from the experimental plots described in this paper. Here also, it was found that the bulk and carbohydrate content of the roots progressively diminished with the frequency of cutting. Clipping at fortnightly intervals led to an almost complete exhaustion of root reserves in these species irrespective of fertiliser treatment. (The detailed results of this investigation are to be published shortly.)

It is realised that the results of such clipping experiments cannot without reservation be applied to actual grazing conditions. Grazing animals do not usually defoliate the vegetation so completely, though they occasionally uproot whole plants. Grazing by animals is largely selective, so that desirable species are more severely affected than less desirable ones. Selective grazing, together with trampling and manuring, leads to changes in the botanical composition of the sward as shown by Glover (1938) and van Rensburg (1939 and 1941). Though all such factors are not included in clipping experiments more recent investigations of the writer (still unpublished) have shown that the gross effects of frequent close grazing are at least very similar to those of frequent clipping.

From the results of these clipping experiments, taken in conjunction with subsequent grazing experiments, it may be concluded that continued close grazing at short intervals will sooner or later lead to irreparable damage. Intensive grazing at one time of the year should be followed by sufficiently long rest periods at other times of the season. Where such controlled grazing is not possible on account of the lack of fenced paddocks,

the number of grazing animals per unit area should be limited to such an extent as to avoid overgrazing. On the type of veld investigated, a maximum level of productivity can be maintained for any length of time only by moderate grazing use.

## SUMMARY.

Quadrats in fertilised and unfertilised plots of natural, undisturbed veld were subjected to a series of different clipping treatments for two successive years, viz., cutting once, twice, four, nine and sixteen times per season.

The nitrogen, phosphorus and potassium content of the herbage was increased by fertiliser treatment, and even more so by frequent clipping, whilst the calcium content was little affected by either treatment.

The herbage yields were raised by the application of fertilisers, but were reduced by more frequent clipping, the degree of reduction being intensified in the second season, indicating a cumulative effect.

Maximum yields of nitrogen, phosphorus and potassium per unit area were obtained in the herbage cut at two-monthly intervals (or four times a season), whilst the highest amounts of calcium were present in the herbage cut twice a year. Clipping nine or sixteen times per season significantly decreased the total yields of nutrients. The beneficial effect of fertiliser treatment on the total nutrient yields was most pronounced with four clippings per year.

The bearing of these results on practical problems of pasture management is discussed.

## ACKNOWLEDGEMENTS.

Thanks are due to Professor J. Phillips, Head of the Botanical Department, University of the Witwatersrand, for his interest and for the facilities provided in his Department; to Mr. D. Meredith for helpful criticism; and to the National Research Council and Board of South Africa for financial assistance.

## REFERENCES.

Du Toit, P. J. Louw, J. G. and Malan, A. I.: "A Study of the Mineral Content and Feeding Value of Natural Pastures in the Union of South Africa." IV. "The Influence of Season and Frequency of Cutting on the Yield, Persistency and Chemical Composition of Grass Species." *Onderstepoort Jour.Vet.Sci. & Anim.Ind.*, **5**: 215-270 (1935).

Glover, P. E. and Van Rensburg, H. J.: "A Contribution to the Ecology of the Highveld Grassland at Frankenwald, in Relation to Grazing and Burning." *This Journal*, **35**: 274-279 (1938).

Hall, T. D., Meredith, D. and Murray, S. M.: "The Productivity of Fertilised Natural Highveld Pastures." *This Journal*, **34**: 275-285 (1937).

HALL, T. D., MEREDITH, D. and MURRAY, S. M.: "Fertilising Natural Veld and its Effect on Sward, Chemical Composition, Carrying Capacity and Beef Production." *This Journal,* **37**: 111-129 (1940).

LOUW, J. G.: "The Influence of Frequency of Cutting on Yield, Chemical Composition, Digestibility and Nutritive Value of Some Grass Species." *Onderstepoort Jour.Vet.Sci. & Anim.Ind.,* **11**: 161 (1938).

SMITH, M. F.: "Observations on the Response of Highveld Grassland to Various Cultural Treatments." Unpublished B.Sc. Hons. Thesis, University of the Witwatersrand (1940).

STAPLES, R. R. and TAYLOR, A. J.: "Studies in Pasture Management. A Preliminary Report on the Seasonal Composition of Certain South African Pasture Grasses in Relation to their Manuring and Intensity of Grazing." *This Journal,* **26**: 139-153 (1929).

TAYLOR, A. J.: "Studies in Pasture Management: A Further Report on the Seasonal Composition of Certain South African Pasture Grasses in Relation to their Manuring and Intensity of Grazing." *This Journal,* **28**: 205-206 (1931).

VAN RENSBURG, H. J.: "A Further Contribution to the Ecology of the Highveld Grassland at Frankenwald, in Relation to Grazing." *This Journal,* **36**: 238-245 (1939).

VAN RENSBURG, H. J.: "A Comparison of Quadrat Results and Phenological Data in a Series of Highveld Grassland Grazing Experiments subjected to Different Treatments over a Period of Six Years." *This Journal,* **38**: 186-197 (1941).

WEINMANN, H.: "Effects of Defoliation Intensity and Fertiliser Treatment on Transvaal Highveld." *The Empire Journal of Experimental Agriculture,* **11**: 113-124 (1943).

# SOME METHODS OF CONTROL OF UNWANTED VEGETATION

BY

PROF JOHN PHILLIPS,

*University of the Witwatersrand, Johannesburg.*

*Read 28th June, 1943.*

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 135-146*
*November, 1943.*

# PRELIMINARY OBSERVATIONS REGARDING SOIL EROSION ALONG THE SOUTH AFRICAN RAILWAYS.

BY

R. ROSE INNES.

*With 9 Diagrams.*

*Read 28th June, 1943.*

Increasing public and scientific interest has been aroused in recent years concerning the rôle played by public works as a cause of soil erosion. The road and railway systems of the country have been singled out by some as cases in point. No comprehensive report on the subject has been published in this country.

It was therefore decided to survey a chosen section of railway line, with the following objects in view:—

1. To discover if soil erosion existed and if so, to what extent.
2. To ascertain the agents responsible for any soil erosion discovered.
3. To note if constructional mistakes possibly causing soil erosion on old railway lines had been repeated on new ones.
4. To suggest remedial measures.
5. To outline a policy that would help to prevent further erosion.

## METHODS.

The methods used were entirely observational. A 149-mile section of railway between East London and Queenstown was chosen for survey. In a preliminary survey made by train, suitable areas were selected for closer inspection. The main survey was done in part by foot, in part by slow goods train. Approximately 50 miles of ground were closely studied and covered on foot; 42 miles on the track itself, the remainder in the immediate vicinity. The survey covered a four-day period, beginning on 2nd February, 1943.

## FINDINGS.

Generally speaking, it was found that soil erosion is most frequently the result of a complex of contributary causes, though nearly always initiated by railway construction work. Farming malpractices on adjoining private land, though of a

secondary nature, also aid erosion. The degree of soil erodibility —another secondary factor—had also to be taken into account. In certain cases, the responsibility for soil erosion could be ascribed to the work of the South African Railways (S.A.R.) alone.

The major causes of erosion are comparatively few but occur repeatedly along the section of railway studied. These causes are summarised below in three sections: firstly, those connected with S.A.R. construction work only; secondly, those in which the influence of the S.A.R. is combined with that of private individuals; thirdly, those due to the combined influence of the S.A.R. and factors inherent in natural conditions. Possible remedies are discussed in each case.

*A.—Causes Due to the Influence of S.A.R. Construction Work.*

I. Numbers of dual-purpose culverts have been constructed in embankments. These culverts are intended primarily to drain flood water but are also used as passage ways (termed "cattle creeps" by the engineers) for stock animals of all kinds. Constant trampling has denuded the soil of its vegetation fanwise on either side of the culvert, at the very point where storm water reaches a high velocity and its greatest volume per unit area, and where the strongest soil-binding vegetal cover is consequently essential. This is the most frequent and most serious cause of erosion seen on the survey.

There is only one remedy: the culverts must be used only as drainage ways, never as stock passages. To facilitate passage of stock animals from one side of the line to the other; light, standardised stock bridges might be thrown across cuttings. If this should prove too expensive, or if cuttings do not exist in the locality, then level crossings must be made at points where storm water flow is at a minimum.

II. Inadequate dispersal of storm water effluent from culverts appears to be the next most serious cause of erosion. Water issuing from culverts is usually allowed to find its way down slopes of varying steepness or, what is worse, is sometimes led directly down the slope in a straight trench. Few, if any, adequate systems of culvert effluent dispersal on steep slopes were seen, either on old or new railways between Queenstown and East London. Many serious dongas have developed, sometimes due entirely to the influence of railway construction work.

Erosion of this type can easily be obviated by constructing a simple system of contoured dispersal furrows, designed to distribute culvert effluent over as wide an area as possible on either side of the exit. The outlay would be small, the savings great.

III. The cutting drainage system is bad and contributes to soil erosion at many points, though from the point of view of

working efficiency, the railway is adequately drained. The rim of the cutting on the upper slope is always paralleled by a drainage ditch (termed a "catch-water drain") which runs from the highest point near the cutting's centre to the lowest point at its entrance. This catch-water drain prevents water from seeping over the rim into the cutting from the slopes above it. These drains are not carried under the line at the end of the cutting but are prolonged to the middle of the adjacent embankment, where the water is allowed to escape through the culvert there.

The culvert may be more than a quarter of a mile from the crest of the cutting and if the slope is steep and the soil erodible the drains erode with great rapidity. The volume of water is further swelled by the addition of drainage water from the interior of the cutting (these are called "table drains"). This system is usually reflected on the opposite side of the drainage basin, except that table drains on that side do not contribute but follow the slope of the line. (See Diagram I.)

The catchment area provided by the furrows and cuttings is larger than that contributing run-off to the stream-bed under natural conditions. The water is funnelled through the culvert —violently, if it is too narrow—and discharged into the natural stream-bed (often already eroded) on the lower slope. No contoured dispersal furrows are made here and erosion progresses at great speed. Factors mentioned under other heads may aggravate the process.

Several measures may be adopted to deal with the conditions described. These measures are outlined below:—

1. If the slopes are not too steep to cause erosion in the furrows themselves, the catch-water drains should proceed from the crest to the end of the cutting and then be led under the railway at that point. Catch-water and table drains should join at the cutting entrance and pass under the line at that same point. On reaching the lower slope the combined flow should be adequately distributed in a system of contour furrows. (See Diagram II.)

2. If the slopes are steep enough to cause erosion in the catch-water drains, water must be led away from the rims of the cuttings in a series of small contoured catch-water furrows. A larger "pick-up" furrow, running close to the contour, would gather their overflow and transport it in the opposite direction towards the railway line. On reaching the cutting mouth it would be joined by the table drain, and the combined flow be led beneath the line at that point. Dispersal on the lower slope would be the same as in I. (See Diagram III.)

It should be noted that in both the above plans, surplus drainage water is diverted from the culvert and dispersed elsewhere. It might also be necessary to disperse the culvert effluent in contour furrows on both sides of the exit, particularly if erosion has already begun there.

3. This is a makeshift plan which would attempt to alleviate the trouble without altering furrows already made. It would probably only succeed on gentle slopes and would possibly prove more costly in the long run, since the root causes of erosion are not removed.

The stream bed would be dammed just below the culvert exit. Effluent from the culvert would fill the dam and be led away on either side in contour furrows. (See Diagram IV.) The plan would prevent further erosion in the stream-bed below the culvert but does nothing to stop it on the upper slopes.

Erosion on the upper slopes might be alleviated by carrying catch-water and table drainage away from the line in contour furrows and allowing it to drain slowly into the stream-bed somewhat above the culvert entrance. This would not reduce the total volume of water passing through the culvert but would provide a steadier flow over a longer period of time. (See Diagram V.)

IV. Without exception, all the drainage furrows studied were narrow, deep in comparison to their breadth and bare of any vegetation. Nearly all were eroding, slowly or rapidly, according to steepness of slope, erodibility of soil and volume of water carried.

To prevent erosion along drainage furrows constructed in soil, certain simple principles should be followed. Moving water should be spread over as wide an area as is conveniently possible, consistent with effective drainage. The furrows, therefore, should be wide, comparatively shallow and well-vegetated throughout. (See Diagrams VI. and VII.)

V. The angle at which culverts penetrate embankments is sometimes the cause of erosion on slopes below the railway. Culverts almost invariably pierce embankments at right angles. The reason is that this is the shortest possible route from one side to the other and construction consequently costs less in terms of materials, labour, time and money.

Railway embankments most frequently cross stream-beds obliquely. A culvert placed at right angles to the embankment does not therefore coincide with the direction of natural drainage flow. Two possible methods may be used to construct culverts of this kind.

1. The culvert entrance may be built in the bed of the stream. Water is picked up directly from the bed on the upper slope, carried through the embankment and deposited on the lower side, not in the stream-bed but to one side and above it. (See Diagram VIII.)

Water discharged on to the bank above the stream-bed in this manner is certain to cause erosion unless specially dispersed. But dispersal on the contour can take place in only one direction, since the culvert exit lies to one side of the centre of the stream-bed and only that side can be used.

2. The culvert exit may be built to lie in the stream-bed, while the entrance lies to one side and above the natural water level. (See Diagram IX.) In this case a small dam must first form at the base of the embankment before the water reaches a level high enough to allow it to flow through the culvert. This is probably undesirable from the engineering viewpoint, but can be overcome if necessary by diverting the stream-bed to the mouth of the culvert. In this case the dam would not then form.

This plan is more desirable than the other. There is very little danger from erosion because the water is first checked at the embankment and then discharged into the natural bed. If the latter is already eroded, however, contour furrows can be led off on both sides of the bed and erosion checked by adequate dispersal.

VI. Many miles of firebreaks have been made in private ground flanking the railway. These are made by permanently denuding a strip of soil of its vegetation. Erosion has taken place at many points on these firebreaks, especially where slopes are steep, soil erodible and the volume of water flowing over them large.

There seems to be no way of retaining a permanent firebreak of this kind and preventing erosion on it at the same time. A series of cross walls for diverting water flow would trap silt and seeds and consequently cause vegetation to develop, thus defeating its purpose. This type of firebreak might be replaced by similar breaks enduring for one season only, or by ploughed strips shifted at each new season, or, best of all, by burned firebreaks. All of these, however, involve expense. The last is the best from the point of view of preventing soil erosion.

VII. Pits have been excavated at certain points near the railway to supply material for embankments and ballast. (These are termed "borrow pits.") No attempt has been made to vegetate abandoned pits and erosion has taken place in some.

Erosion occurring in borrow pits could be easily prevented by sloping the banks, diverting flood water from them and by planting stoloniferous grasses. Each pit differs widely from its fellows and would have to be treated as an individual problem.

VIII. None of the recently constructed embankments has been stabilised by vegetation and some are beginning to erode somewhat on to fields below them.

Embankments constructed of broken stone present no erosion problems, but on soil embankments a few planted sods of stoloniferous grasses would rapidly cover and bind the loose soil. This is not a serious cause of erosion and even when left alone the condition does not remain for long.

Of the eight causes of erosion outlined above, all—with the possible exception of VI. (breaks not made because the line is

not yet in use) and doubtful exception of VII., are being repeated on new railway now under construction. This is perhaps the most important single point that emerges from the survey.

*B.—Causes Due Partly to the Influence of Farming Malpractices on Private Ground Adjoining the Railway.*

IX. Over-grazing of veld adjoining the railway is the most important cause of erosion in this category. Some culverts studied showed that the effluent trenches inside the S.A.R. enclosure were well vegetated and showed no signs of erosion, whereas the same trenches outside the fence had developed into large dongas in the over-grazed, semi-denuded pasture land. Such dongas were seen on both sides of the railway, either tearing their way downwards or eating slowly upwards on the slopes above.

The remedy is simple: stop over-grazing and repair damage already done. The application, however, is difficult because it impinges upon the principle of private ownership and the rights of individuals to make or mar their soil as they will. The approach here might best be made on contract lines (based, perhaps, on such legislation as Act 13 of 1941, which enables the Government to declare any portion of the Union a conservation area, irrespective of the owner's wishes), the contracting parties being the Division of Soil and Veld Conservation (advised by the S.A.R.) on the one hand, and the private individual on the other. Once contracts were made, work could proceed under the guidance of the Division, the expense being borne partly by the Government and partly by the individual on a subsidy basis.

X. Ploughing land in the path of storm water effluent from railway culverts is another fairly frequent cause of erosion. Even small streams have caused serious erosion in this way because denuded loosened soil cannot withstand the shock of flood water.

The remedy is simple and easy to apply. It consists in leaving permanently grassed waterways through ploughed fields. The ground area sacrificed is negligible, stream flow is steadied and erosion stopped. Plans of this kind might also be promoted on a contract basis. They are easier to put into operation than those described under IX., because they involve no radical changes in the farming system and the area affected is small.

*C.—Causes Due partly to Natural conditions.*

XI. Soil erodibility varies widely from one soil type to another. Nothing practicable can be done to alter the degree of erodibility of a soil, but erosion can be prevented by taking special precautions, as outlined above, at the start of construction work.

It must be realised that in a very high percentage of cases soil erosion is not due to any one of the causes described, but to several. One instance seen near Cathcart can be used as an illustration. A very large donga has developed there below a culvert of the cattle-creep type. This erosion owes its origin to trampling by stock, to concentration of flood water from a road nearby, to erosion on an adjacent firebreak, to dongas shedding flood water from old ploughed lands on the mountain-side above, and, lastly, to erodible soil.

The eleven causes outlined above have been separated as far as possible—as have the remedies suggested for each case—for purposes of accurate description.

## Conclusions.

1. Serious erosion exists at many points along the railway surveyed.

2. This erosion is caused in part by S.A.R. work alone, in part by the combined influence of the S.A.R. and private land-owners, in part by the combined influence of the S.A.R. and factors inherent in natural conditions. As far as could be judged, erosion in the immediate vicinity of the railway is always initiated by the S.A.R. though the blame is by no means completely theirs. Much of the erosion studied would probably not have taken place had not the land adjacent to the railway been maltreated. It could be said with equal truth, however, that the same erosion would probably not have started had not the railway been built.

3. A most disturbing fact is that the major constructional mistakes causing erosion on old railways are being repeated on new sections.

4. Almost all the causes of erosion described could have been eliminated early, though probably at higher constructional costs.

## Recommendations.

The situation as seen on this survey, and probably in many other parts of the Union, calls for immediate action. The forces of soil erosion are cumulative in action and with the passage of time become increasingly difficult to cure.

The first necessity is to make wider surveys of a similar kind along railways in each of the climatic zones of the Union. The main causes of erosion could then be listed and a well-defined construction policy laid down for the guidance of all S.A.R. construction engineers.

To say that the prosecution of a policy of this kind would cost more money is probably correct, but may not be used as an argument for shirking the issue. If the problems are not faced now they must inevitably be met later in far more menacing form. Railways are useless things unless there be

goods and people to carry; both depend ultimately upon the maintenance of our soils.

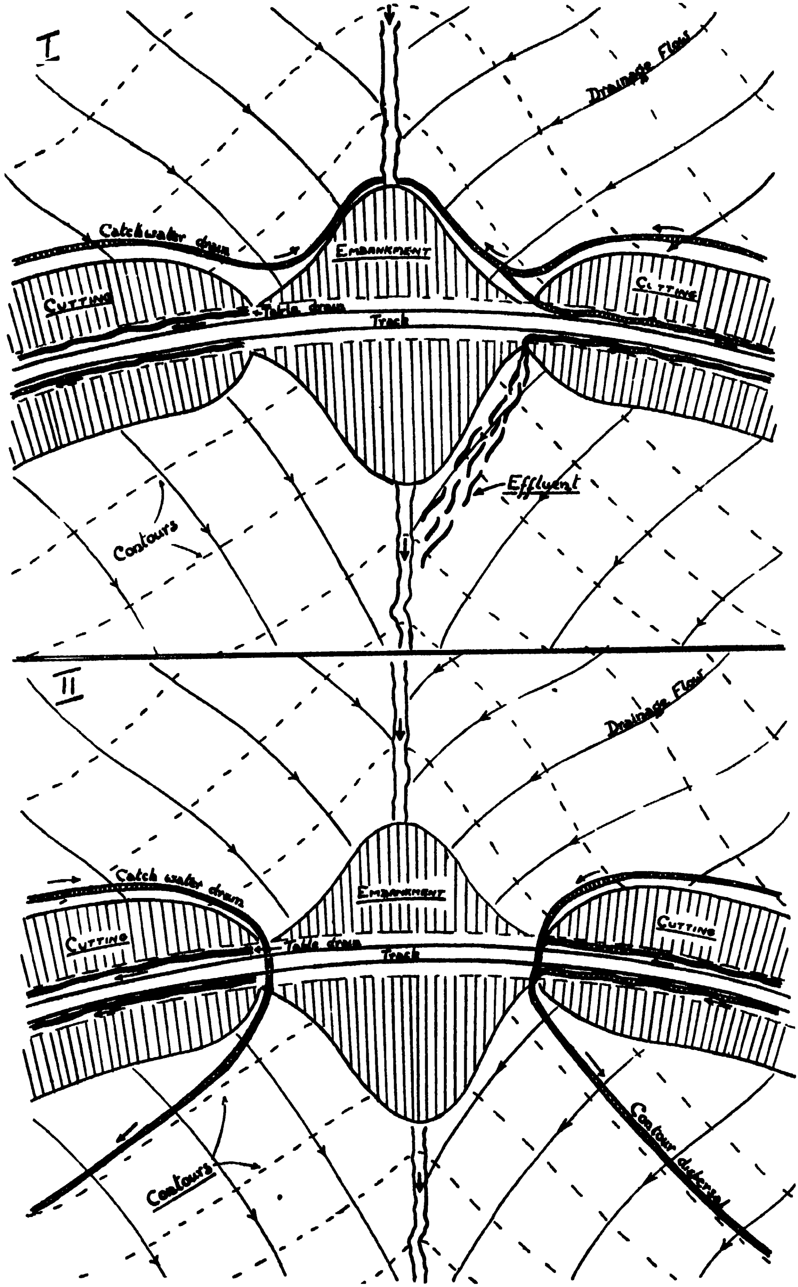
The engineer's viewpoint, naturally enough, is that the railway must be kept working at all costs; he well knows that washaways may mean the loss of thousands of pounds for every day's delay of traffic. Provided the track is efficiently drained and kept in smooth working order, he is not greatly concerned as to how it is drained or what the effects of drainage may be in terms of soil erosion. Much could be done to eliminate narrow views of this kind—and thus soil erosion itself—by enforcing a policy of the type advocated and by releasing funds for doing the work.

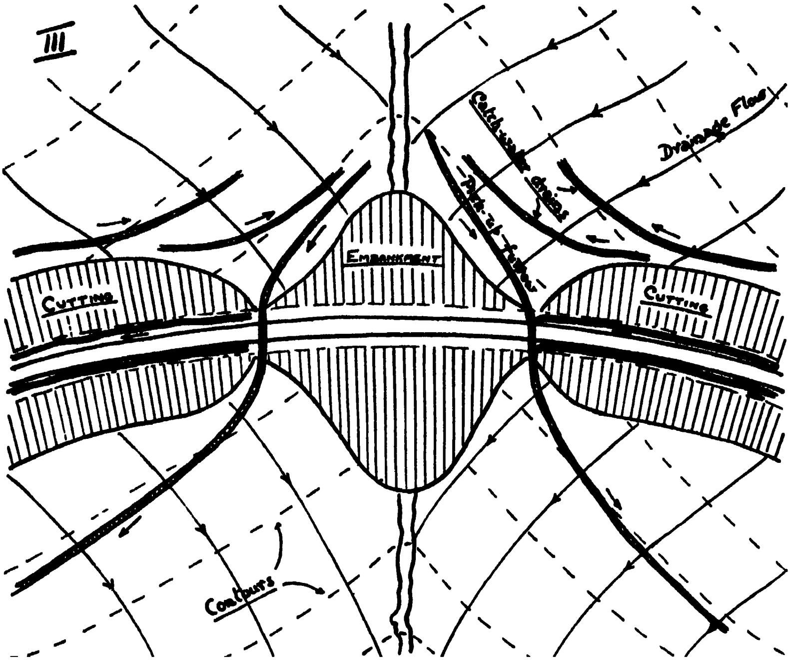
As far as private individuals may be held responsible in part for erosion adjacent to the railways, the approach could probably best be conducted as outlined above. It is necessary that a good working basis of suitable legislation be at hand for work of this kind.

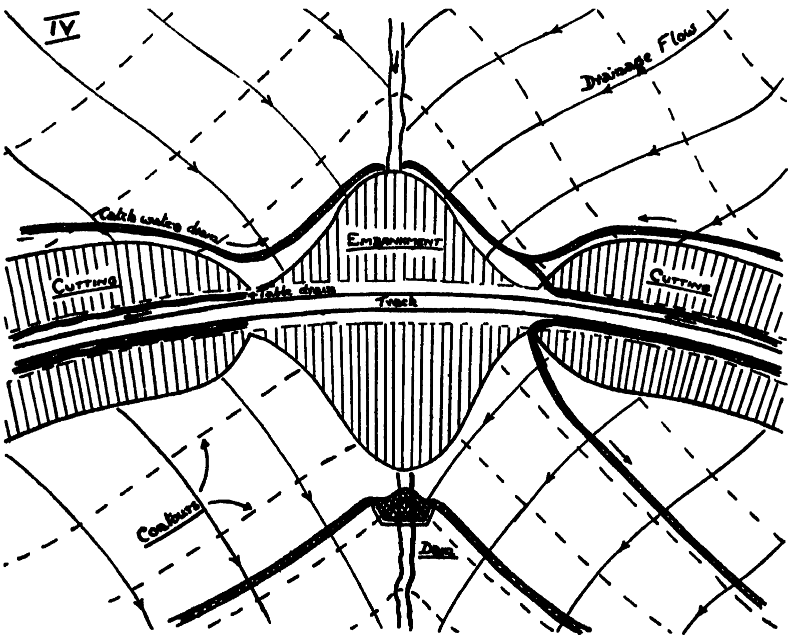
A prerequisite to any such policy is that there should be close co-opeeration between the S.A.R. and the Division of Soil and Veld Conservation. The fact that a Government Department, such as the S.A.R., is in many cases solely responsible for soil erosion is bewildering to those who are aware of the " save our soil " campaigns of the Division of Soil and Veld Conservation, the National Veld Trust and other official and semi-official bodies.

ACKNOWLEDGEMENTS.

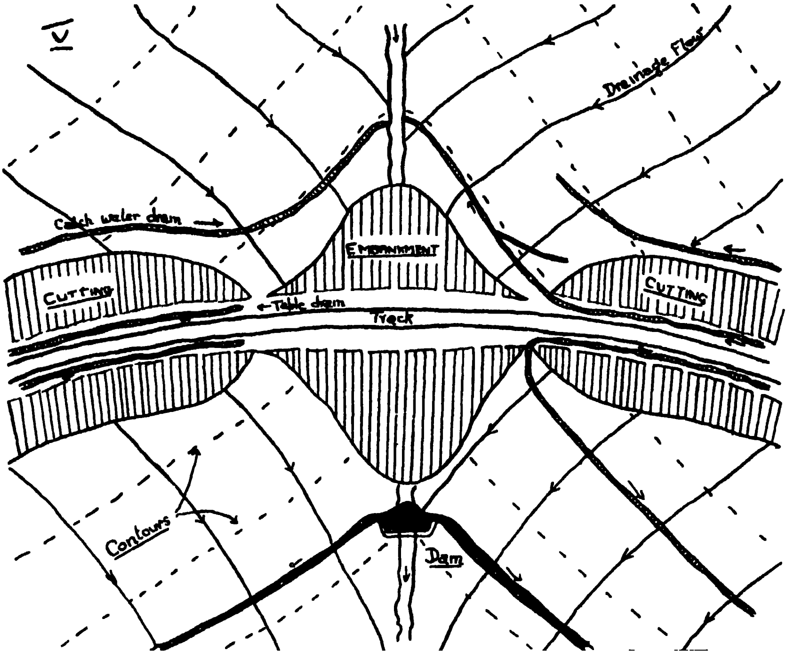
I am indebted to the S.A.R. authorities for permission to inspect the railway between Queenstown and East London, and to certain engineers of that department for information, advice and criticism.


I
Drainage Flow
Catchwater drain
Embankment
Cutting
Table drain
Track
Effluent
Contours
II
Drainage Flow
Catch water drain
Embankment
Cutting
Table drain
Track
Contours
Contour diversion

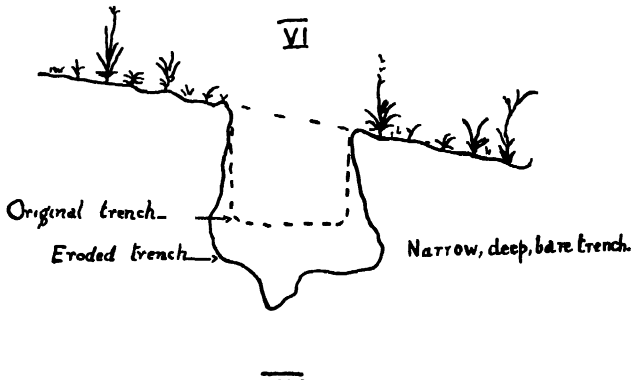

III
Catch-water drains
Drainage Flow
Pitch-up furrows
Embankment
Cutting
Cutting
Contours


IV
Drainage Flow
Catch water drain
Embankment
Cutting
Cutting
Table drain
Track
Contours
Dam

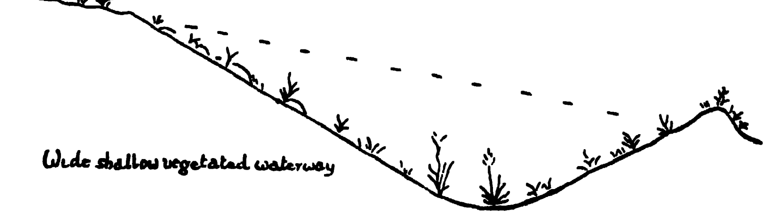
V

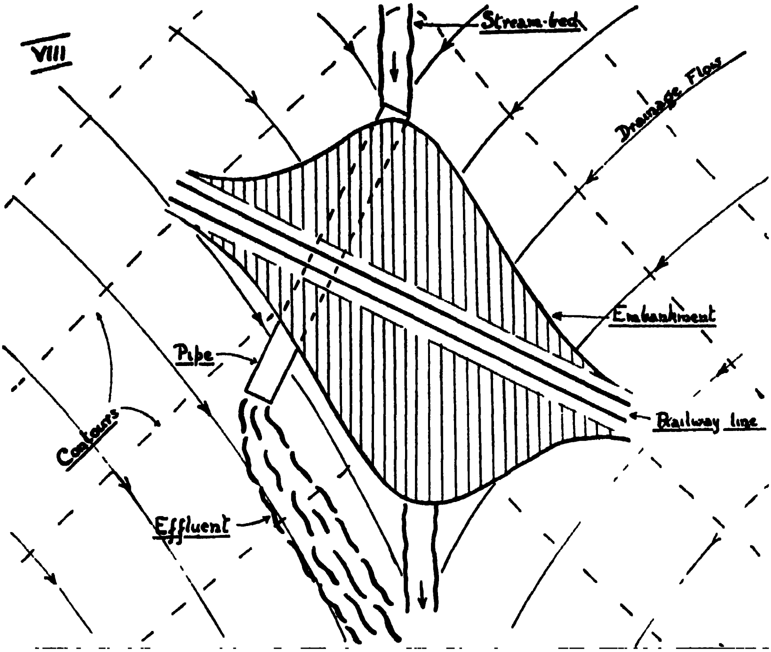

Drainage Flow
Catch water drain
Embankment
Cutting
Cutting
Table drain
Track
Contours
Dam

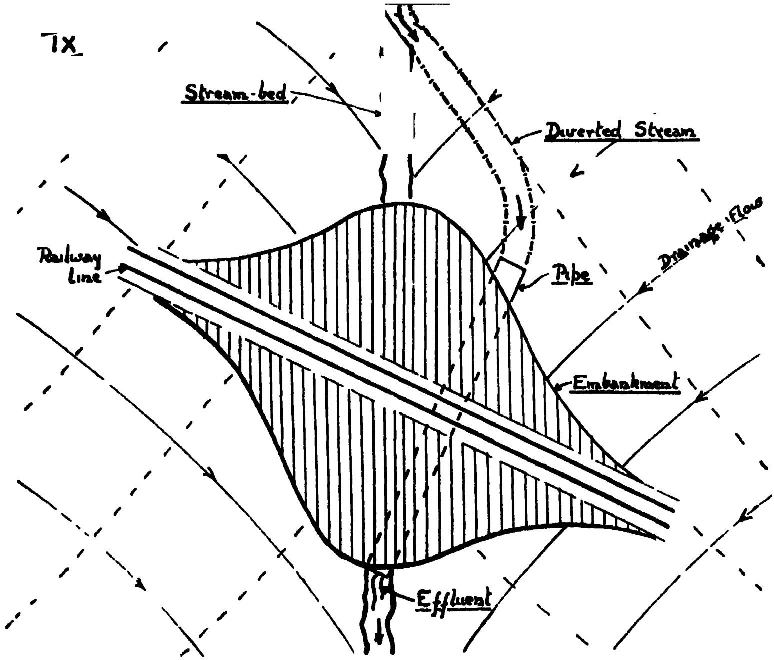
VI


Original trench
Eroded trench
Narrow, deep, bare trench.

VII


Wide shallow vegetated waterway


VIII
Stream-bed
Drainage Flow
Embankment
Pipe
Railway line
Contours
Effluent


IX
Stream-bed
Diverted Stream
Drainage Flow
Railway Line
Pipe
Embankment
Effluent

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 147-150*
*November, 1943.*

# THE RESPONSE OF TWO VARIETIES OF APPLE CUTTINGS TO PHYTOHORMONE TREATMENT.

BY

P. MUNRO,

*Read 28th June, 1943.*

ABSTRACT.

The propagation of apple varieties by means of stem cuttings has long been a problem. Very different results have been obtained, some workers finding the rooting of these cuttings easy, while others have had little or no success. Nowhere in the literature reviewed was a simple reliable method of rooting apple cuttings reported. It was thought that such a method could be established through the use of phytohormones, which in recent years have played a very important part in vegetative propagation.

*Methods and Material Used.*

1. Delicious and Rome Beauty apple varieties were used for experimental work. Cuttings were made from one-year-old shoots taken from trees varying in age from 10-20 years.

2. All cuttings were classified into two groups: (a) Apical cuttings, which were characterised by the possession of an apical bud as well as lateral buds. (b) Basal cuttings which were characterised by the possession of lateral buds only.

3. Sand was used as a rooting medium.

4. The growth-promoting substances used for the stimulation of cuttings were Hortomone A, indole-butyric acid, naphthalene acetic acid, and B-napthoxyacetic acid. Vitamin B or aneurin was used in combination with an auxin in some cases. The concentration of auxin used varied from 40-100 mg. per litre of distilled water. The solution method was used for the stimulation of cuttings by growth-promoting substances

*Summary of results obtained from experiments with Delicious stem cuttings.*

1. No rooting occurred regardless of the treatment given.

2. Bud growth occurred in high percentage in the case of cuttings treated with high concentrations of auxins.

3. Very little callus formation occurred.

4. A large percentage of rot occurred, due to fungal disease.

*Summary of the results obtained from experiments with Rome Beauty cuttings.*

1. Rooting occurred among young one-year-old cuttings. It is significant that all the rooted cuttings, with the exception of one, were of the apical type.

2. The two concentrations of auxin producing roots on Rome Beauty cuttings were 40 mg. and 80 mg. per litre of indole-butyric acid. No other growth-promoting substances produced roots.

3. A heavy and high percentage of callus growth occurred on both stimulated and unstimulated cuttings. Roots occurred only on stimulated cuttings. The rooting of these cuttings occurred after the cutting had been planted for at least four months.

4. Bud growth occurred only in spring and summer, and only after callus development had reached a certain stage, unlike Delicious, which had a high percentage of bud growth throughout the bud dormancy period.

5. There was a large percentage of rot due to fungal attack.

## Discussion.

The most significant feature of the results obtained from the treatment of two apple varieties cuttings with phytohormones are:—

(1) The very different responses produced in callus and bud growth among the Delicious and Rome Beauty cuttings.

(2) The complete failure to root Delicious cuttings regardless of the treatment given.

(3) The rooting of the Rome Beauty cuttings. In all cases in which rooting occurred excepting one, the rooted cuttings were of the apical type.

(4) The two concentrations 40 mg. and 80 mg. of indole-butyric acid produced roots. No other treatment produced successful results.

It appears that the action of the auxin stimulation is different in the two varieties. In the case of Delicious cuttings the high percentage of bud growth during the winter months is due to the fact that at certain concentrations auxins release bud dormancy. The growth of callus was not activated very much by auxin treatment except in the case of abnormally high concentrations of naphthoxyacetic acid. Here the growth was abnormal and very quickly attacked by fungus.

In Rome Beauty cuttings the responses induced by auxins were what was expected on theoretical grounds. Callus growth was the direct response to auxin stimulation. There was a relationship between the growth and bud activity at a later stage,

bud growth only occurring after callus growth had developed to some extent. The production of roots occurred at a still later stage, and was the result of auxin stimulation and the balanced relationship between callus and bud activity.

The fact that apical cuttings rooted more readily than did basal cuttings, indicates that the juvenility of a cutting is an aspect which must be given important consideration.

## CONCLUSION.

From the investigation of the responses of the two varieties Delicious and Rome Beauty to auxin stimulation, it is obvious that much more work must be carried out involving as many varieties as possible.

It may be found that varieties of apples can be classified with regard to their callus growth, the occurrence of which is a varietal characteristic, and their response to auxin treatment. On this basis separate treatments for Delicous cuttings and related varieties must be found. The problem with regard to Rome Beauty cuttings and possible related varieties is much more simple.

## BIBLIOGRAPHY.

BONNER, J.: "The action of the growth hormone." *Journ.Gener. Phys.*, **17** (1933).

BONNER, J. and THIMANN, K. V.: "Studies on the Growth Hormones of Plants." *Journ.Gen.Phys.* **19** (1935).

BOYSEN JENSEN, P.: "Growth hormones in plants." Translated and revised by G. S. Avery, Jnr. and P. R. Birkholder. McGraw Hill Book Co. (1936).

CHILD, C. M.: "Physiological foundation of Behaviour." New York: Henry Holt & Co. (1924).

CHILD, C. M.: "The beginning of Unity and Order." (1929).

GARDNER, F. E.: "Etiolation as a method of rooting apple variety stem cuttings." *Amer.Soc.Hort.Sci.* (1936).

HITCHCOCK, A. F.: "Effect of Peat Moss and Sand on the Rooting Responses of Cuttings." *Bot.Gaz.*, **86:** No. 2 (1928).

HITCHCOCK, A. E. and ZIMMERMAN, P. W.: "Effect of growth substances on the rooting responses of cuttings." *Cont. Boyce Thompson Inst.*, **8:** No. 1 (1936).

HITCHCOCK, A. E. and ZIMMERMAN, P. W.: "Unusual physiological responses induced on plants by capping with black cloth." *Cont. Boyce Thompson Inst.*, **10:** No. 4 (1939).

HITCHCOCK, A. E. and ZIMMERMAN, P. W.: "Comparative activity of root inducing substances and methods for treating cuttings." *Cont. Boyce Thompson Inst.*, **10:** No. 4 (1939).

HITCHCOCK, A. E. and ZIMMERMAN, P. W.: "Effects obtained with mixtures of root inducing and other substances." *Cont.Boyce Thompson Inst.*, **11:** No. 2 (1940).

HITCHCOCK, A. E. and ZIMMERMAN, P. W.: "Formative effects induced with B-naphthoxyacetic acid." *Repr. Boyce Thompson Inst.* (1941).

LOEB: "The theory of regeneration from a physio-chemical viewpoint." McGraw Hill (1923).

McMartin, A.: "Propagation of the leaf of Acanthus." *Trans & Proc.Soc.Edin.*, **31**: Part 2 (1937).

*Science*, **87**: No. 255. Aneurin and the rooting of cuttings. (Feb. 1938).

Stoutmeyer, V. T.: "Regeneration in various types of apple wood." *Res. Bull.*, 220, Amer. Iowa (Sept. (1937).

Swingle, C. F.: "A physiological study of rooting and callusing in apple and willow." *Journ.Agric.Res.*, **39** (1927).

Swingle, C. F.: "Regeneration and vegetative propagation." *Bot. Review*, **7**: No. 7 (1940).

Thimann, K. V.: "Auxin and the inhibitions of plant growth." *Harv. Biol. Lab. Biol. Review of Cambridge Phil. Soc.*, **14**: No. 3 (1929).

Thimann, K. V.: "Studies on the growth hormones of plants. The distribution of growth substances in plant tissues." *Journ.Gen. Phys.*, **18** (1934).

Thimann, K. V. and Delisle, A. L.: "The vegetative propagation of difficult plants." *Journ. Arnold Arbor.*, **20** (1939).

Zimmerman, P. W. and Wilcoxon, F.: "Several chemical growth substances which cause the initiation of roots and other responses in plants." Cont. *Boyce Thompson Inst.*, **7**: No. 3 (1935).

## *MICROCOCCA* BENTH, AND *ERYTHROCOCCA* BENTH.

BY

Dr. E. P. Phillips,

*Chief, Division of Botany and Plant Pathology.*

*Read 28th June, 1943.*

## *BUXUS* LINN. AND *NOTOBUXUS* OLIV.

BY

Dr. E. P. Phillips,

*Chief, Division of Botany and Plant Pathology.*

*Read 28th June, 1943.*

South African Journal of Science, *Vol. XL, pp. 151-152*
*November, 1943.*

# AN INVESTIGATION INTO THE CHEMICAL NATURE OF FROST INJURY IN YOUNG MAIZE PLANTS.

BY

Leonora Reinhold.

Abstract.

This paper reported a physiological investigation into the nature of frost injury in young maize plants.

A brief review of the literature was presented, summarising the current hypotheses explaining the cause of death from cold and the theories accounting for resistance.

Exposure to low temperature was observed to result in an increase in osmotic pressure, in the electrical conductivity of plant extracts, in dry matter content, in soluble nitrogen expressed as a percentage of total nitrogen, soluble phosphorus expressed as a percentage of total phosphorus, and in sugars. The proportion of reducing to total sugars was decreased. The increase in the proportion of soluble nitrogen and phosphorus apparently indicated cleavage of complex organic substances. Hydrogen-ion concentration was unaffected by continuous exposure.

The changes indicated above were observed to increase progressively with increased length of the period of exposure. They appeared to be closely related to the thawing process, and were not observed if harvesting followed exposure immediately. The changes reached maximum magnitude after a 24-hour thawing period, and had diminished considerably 72 hours after exposure. They were thus, to an extent at least, reversible. They were more pronounced in plants thawed at 35° C. than in those thawed at 23° C. The rate at which the plants were cooled during exposure did not affect the magnitude of the physiological changes.

Plants repeatedly exposed for short periods differed from those chilled continuously in the following respects: the osmotic pressure and sugar content of the repeatedly exposed plants were very low, not high as in the continuously exposed plants; the proportion of soluble nitrogen in the repeatedly exposed plants was extremely high; the pH of these plants was also high; the proportion of reducing to total sugars was increased, and the water content not decreased. That the repeatedly exposed plants had not undergone any form of hardening process was demonstrated by the fact that their chemical composition did not correspond to that of hardened plants.

The plants exposed to continuous cold appeared to be very much more severely injured than those repeatedly exposed for

short periods. This injury was apparently not connected with the breakdown of proteins, since the latter process, as manifested in an increased soluble nitrogen content, occurred to a greater extent in the repeatedly exposed than in the continuously exposed plants. The two sets of plants differed further with respect to sugar and water content. (See above.) The accumulation of sugars as a result of exposure is widely regarded as a protective mechanism against frost injury. It was therefore assumed that the injury of the continuously exposed plants was chiefly connected with the lowered water content. This finding emphasises the similarity between frost and drought injury.

## BIBLIOGRAPHY.

CHANDLER, R. C.: "Bound Water in Plant Sap and some Effects of Temperature and Nutrition Thereon." *Plant Phys.*, **16**: 785-798

CHANDLER, W. H. and HILDRETH, A. C.: "Evidence as to how Freezing Kills Plant Tissue." *Proc.Amer.Soc.Hort.Sci.*, **33**: 27-35 (1935).

HARVEY, R. B.: "The Hardening Process in Plants and Developments from Frost Injury." *Journ.Agric.Res.*, **15**: 83 (1918).

ILJIN, W. S.: "Bestimmung des Zuckers mittels Fehlingscher Lösung und Zentrifugierens." *Biochem.Zeit.*, **193**: 322-325 (1928).

MAXIMOV, N. A.: "Chemische Schutzmittel der Pflanzen gegen Erfrieren." *Ber.Bot.Ges.*, **30**: 52-65, 293-305, 504-516 (1912).

MAXIMOV, N. A.: "The Plant in Relation to Water." George Allen & Unwin, Ltd. (1929).

NEWTON, R. and BROWN, W. R.: "Frost Precipitation of Proteins of Plant Juice. *Can.Journ.Res.*, **5**: 87-110 (1931).

SCHAFFNIT, E., and LÜDTKE: "Beiträge zur Kenntnis von Kaltewirkungen auf die Pflanzliche Zelle. *Mitt.Phytopath.Zeit.*, **4**: 329-386 (1932).

SELLSCHOP, J. P. F. and SALMON, S. C.: "The Influence of Chilling above the Freezing Point on Certain Crop Plants." *Journ.Agric. Res.*, **37**: 315-338 (1928).

WEINMANN, H.: "On the Autumnal Remigration of Nitrogen and Phosphorus in *Trachypogon plumosus*."...*Journ.S.A.Bot.*, **8**: 179-196 (1942).

WILHELM: "Untersuchungen über das Verhalten sogenannter nicht eisbestandigenen Kulturpflanzen bei niederen Temperaturen, unter besonderer Berücksichtigung des N-Stoffwechsels." *Phytopath.Zeit.*, **8**: 337-361 (1935b).

South African Journal of Science, *Vol. XL, pp. 153-156*
*November, 1943.*

# TRANSPLANTING OF GRASSES: SOME OBSERVATIONS

BY
Dr. R. J. Jordan.

*Read 28th June, 1943.*

The transplanting of perennial grasses from one habitat to another has so far not aroused much interest among botanists. It is, however, a most important process in a country depending so much on its grass cover as South Africa. More knowledge and experience about the phenomena connected with it may prove to be important for a future and possibly much extended practice of grass transplantation.

The factors involved in a change of habitat and new adaptations are complex and involved, and although they merit detailed discussion, space here permits only the observations concerned with my planting out of grass varieties from South and East Africa to the vicinity of Pretoria. The grasses belonged mostly to the genera *Cynodon*, *Digitaria* and *Panicum*. All were selected for their ability to grow and spread quickly and so to achieve a good cover in a relatively short time. It is important for this purpose that the shock of transplantation should be overcome by the plant organism without undue delay. Success or failure depends chiefly on the reaction of the individual plant to the cessation or disruption of its water supply. The plant in its new habitat is threatened with water starvation if quick regeneration of epidermal root hairs does not restore the capacity for water absorption. This regeneration actually does take place, but it needs time, some days as a rule, and meanwhile the green parts of the plant lose most of their water through evaporation, wither and frequently die off completely. It is important that various grasses are so differently adapted to acceleration and retardation of their water metabolism. Some varieties transpire more quickly than others. As a rule varieties from arid regions are equipped with some mechanism retarding transpiration and consequently do not die off so easily when transplanted. This was found to be the case with some Digitaria spp. from Bechuanaland and South-West Africa, and also Digitaria var. Thompson's Falls, Panicum Makarikari strain and *Acroceras macrum* (Kazungula strain). In all cases the plants remained altogether green until new growth started. Special adaptation of the green parts may have combined with particularly vigorous growth of new root hairs. Old and new roots together, in about a week's time may obtain through new root hairs sufficient water for normal metabolism and new growth may start. In a number of varieties this process, how-

ever, took a much shorter time, about three days. This was observed in the case of certain Star (Cynodon) grasses as well as *Panicum* spp. Much seems to depend on the time of the year in which transplanting takes place, spring being more favourable than autumn. Transplanting was, however, continued successfully to the end of April.

The majority of transplanted grasses, in many varieties 100 per cent., become acclimatised and adapted to the new environment. After the initial stage which takes one to forty days, and an average of three to seven days, the plant begins to grow again, i.e., the aerial parts start to regenerate and grow. This happens in different ways. Wherever growth starts while the old green parts have not withered at all, there it continues without any particular hiatus. Where on the other hand the green parts have died off altogether, there in many cases these old parts are abandoned and the plant starts by way of regeneration to develop completely new aerial parts, new primary meristematic tissues, directly from the root stock. This has been observed with many plants of the *Star* grasses, as well as with Digitaria Marsibit strain, Digitaria Eldoret strain and others. The plants then look completely dead for some days or weeks until new green leaves break through and begin to grow. In other varieties again the process is different. While some aerial parts die off, others keep alive often the nodes, retarding their metabolism and adapting themselves temporarily to a small water consumption. In this case the plants may look dead too, while actually, at least in the nodes, some phloem cells remain alive, as well as some cells of the old meristematic tissue. In these cases, as soon as the root begins again to function, water is brought up through the xylem and the aerial tissues which had kept alive take up their full function again, readapting their rhythm, becoming turgid and starting with photosynthetic activity. The old stems and leaves become again rigid and green. Details of this process are difficult to investigate. It was found in many instances that nodes with their leaves began to revive while lower internodes still seemed dormant or dead. In these cases either the eye was deceived and strands of phloem at least had remained alive, even in seemingly dead stems, or else water reaching the nodes through dead strands of xylem, stimulated the plant to grow from the nodes in all directions. In this latter case possibly new phloem strands were established by meristematic tissues growing from the nodes and using the old dead cell walls of some internodes as temporary mechanical help, similarly to the growth of thyloses in wood.

It was found that some grasses, when transplanted late in summer, concentrated on producing some inflorescences and were not inclined to surface growth; among these were Digitaria Ngamiland strain and Digitaria Vanduzi River strain. Other varieties do not flower at all before matting is achieved; amongst these were Digitaria Richmond strain and *Digitaria Swazilandensis*. A case apart are the Star grasses. They spend their

first year mainly in spreading and coverage, come into flower late or not at all, while they change their habit in the second year when spreading is discontinued through lack of further space and their aerial parts become more scanty and present a somewhat sparse but tough coverage. However, plants taken from such second or third year plots and transplanted, immediately start to grow with first year habit in the new environment, spreading and covering rapidly. The old parts either die off or may be a positive hindrance in certain cases, retarding the quick coverage. Similar development was observed with other grasses, e.g., with Digitaria Oliphants River strain. Small plants of this variety first begin to grow spreading flat on the ground until a good matting is achieved. Then the growth thickens and mutual competition results in a thick lawn, about four to six inches high or even more. If cuttings are now taken and transplanted, it may happen that all the aerial parts die off; then from the root stock new flat growth will appear, attempting to cover the ground and to mat. If, however, helped by wet weather, the old stems and leaves do not die off, most of the new supplies from the roots flow into the older structures with the effect that matting is retarded. It is not claimed that these experiences constitute sufficient basis for any general scientific rule.

Another group is formed by rhizomatous grasses, like *Panicum repens* or Digitaria Marsibit strain and many kweeks. The underground stems of these transplant very easily. The vigour of growth from their nodes is so strong that they adapt themselves very quickly to new conditions. Time has, however, to be allowed for underground growth until new aerial parts appear or begin to grow.

It has been found quite generally that different root systems behave differently in transplantation. Star grasses, for example, quickly grow simple and strong root systems and easily develop new roots from their nodes. Cynodons with rhizomatous stems develop a more intricate subterranean system of stems and roots; to do that they need more time and frequently one or two months until spreading commences. Some varieties of Panicum develop root systems from nodes in their prostrately spreading flower stems and these roots may be transplanted as well as any others.

So far the individual aspects of transplanting have been discussed. In a more general way, it has been found that transplanting from more favourable to less favourable conditions seems to have a lasting effect upon the plant's organism. The plant then adapts itself to these conditions, i.e., to reduced water consumption, hard and dry soil, little moisture, possibly less carbon dioxide and a different soil micro-flora. The very same stock then retransplanted into more favourable environment will react by thriving more vigorously and by showing all signs of new and successful stimulation. Two beds were

grown in each case with Digitaria Pongola River strain and *Digitaria Swazilandensis*, one bed transplanted from Rietondale, Pretoria, the other from Towoomba (Warmbaths), the latter place being less favourable to the plants. The Towoomba stock, however, originated from Rietondale, too; there was, therefore, no selection by way of seeding between these two stocks. The Towoomba plants in each case outgrew the original Rietondale stock in every respect, growing more quickly and more vigorously. It may be, of course, that the repeated transplantation by itself acted as a strong stimulant in both cases, and it is not intended to draw any scientific conclusion from this practical experience. This does not mean that any grasses from unfavourable regions will thrive in better conditions. That is not the case. Though they adapt themselves in due course, plants have their natural limits and those from arid or semi-arid parts will not succeed in wet or marshy places, or at least not as desired.

After successful transplantation, only experience in every single case can show if the plants will thrive and give the desired permanent cover. After initial success, the end may not be achieved for many reasons. Climatic conditions may prove to be too severe, water supply in particular may be insufficient, the soil may be unsuited, the physical aspect may be wrong, ants may devour the new plants, local weeds and perennials may crowd them out and after a year or two little may be left. Other unexpected or undesired results may occur. On the other hand, there seems to be no doubt but that much improvement in coverage as well as in pasturage can be achieved by way of transplantation of grasses which are unsuitable for propagation by seed on a large scale. Better machinery and better technical devices may serve to make this operation easier and more attractive. Though we are to-day still in the pioneer stage, the war may here at least prove to have some beneficial effect.


## SUMMARY.

(1) Transplanting of perennial grasses involves a heavy shock in the life of the plant. As a rule, new root hairs have to be grown until the plant's water metabolism is restored.

(2) The plant has to adapt itself to the new habitat in many ways and reacts to it in its whole structure. Transplanting often has a stimulating effect upon the plant.

(3) Perennial grasses, in many instances, first begin to mat on new ground, whatever the time of the year may be.

(4) Grasses which have been hardened up, grow more vigorously when transplanted again into more favourable conditions.

(5) The ecological effects being rather complicated, more experimental results are required before any generalisation can be made.

South African Journal of Science, *Vol. XL, pp. 157-161*
*November, 1943.*

# DATA ON THE SUGAR AND STARCH CONTENT OF SOME FODDER PLANTS UNDER DIFFERENT PHYSIOLOGICAL CONDITIONS

Preliminary Report

BY

Dr. M. Henrici.

*Read 28th June, 1943.*

It is well known that some of our best fodder plants, like lucerne and some grasses, suddenly prove poisonous to stock. Good fodder plants of the veld, e.g., *Tribulus terrestris*, show a similar behaviour. In spite of research work the conditions under which such poisoning takes place are ill defined, and any attempt to isolate a poison has been unsuccessful. In the past perhaps too much attention has been given to attempts at the isolation of a poison. To-day the problem is approached from another point of view. The veterinarian maintains that the disastrous qualities of lucerne, for instance, are due to an excess of fermentation. If this be the case, an investigation of the carbohydrates in these plants is essential, and, to begin with, of the metabolism of carbohydrates in the normal plants. When the normal content of the carbohydrates connected with photosynthesis is known, then the disturbed metabolism under well-defined conditions of wilting or special treatment can be considered.

In the present work the following plants were investigated: Lucerne, variety Hunters river and Provence, Algerian oats and *Tribulus terrestris*. The plants were cut in the morning after 10 o'clock, unless otherwise stated. To estimate the normal metabolism during the twenty-four hours, on clear sunny summer days, the plants were cut at 7 a.m., midday, 7 p.m. and at midnight; stems, leaves and flowers being kept separate. The cut plants were immediately placed in alcohol to stop all enzyme reaction. Starch, sucrose, reducing sugars (fructose and glucose) were then determined. Different methods were tried for starch, the directions in Klein's "Handbuch der Pflanzen Analyse," II/1 p. 882 were used. The diastase employed was an excellent Merck preparation. The disappearance of the starch was controlled under the microscope with drops of Iodine-potassium iodide. The sucrose was estimated by Van der Plank's method (Biochemical Journal, 1937), the invertase used being prepared from anchor yeast according to Klein's directions (fortunately the yeast did not contain any reducing sugars).

The reducing sugars total were done by a Bertrand titration or separating fructose and glucose by Van der Plank's method,

using hypoiodide for the oxidation of glucose. A word must be said about the clearing of the solution. At first the usual different lead acetates (normal, basic and bibasic) were used, but on the advice of Dr. J. E. van der Plank all solutions of reducing sugars were cleared with washed anchor yeast.

My thanks are due to Dr. van der Plank for much advice in the sugar determinations. The practical work in the laboratory and in the plots was done by Mr. T. van Coppenhagen, at the Fauresmith Veld Reserve.

At the outset it can be stated that all the investigated plants contained starch, although the actual amount in the different species varied greatly from ½ per cent. in the Gramineae to 7·5 per cent. in lucerne leaves. Cane sugar is also found in all the investigated species and generally in larger amounts than reducing sugars. Glucose and fructose are also found in all the species, but glucose often in only very small quantities. The possibility that in the Gramineae there is still another carbohydrate, fructosan, must not be overlooked, but up to now no other sugar has been isolated.

Table I shows the figures for starch for the lucerne and Algerian oats. The two lucerne varieties do not behave exactly alike. The leaves of " Provence " increase rapidly and having their maximum at noon, decrease in the late afternoon and during the whole night without ever becoming entirely free of starch. " Provence " stems follow the same rhythm. They contain, however, much less starch at any time. Strangely enough, the flowers have their starch maximum in the late afternoon, decrease somewhat in the night, and greatly in daytime. The leaves of " Hunters river "' lucerne have their starch maximum in the late afternoon. The starch decreases slowly towards midnight, more rapidly towards morning, and increases slowly towards midday. The stems of " Hunters river " lucerne do not vary their starch content greatly, a small increase in the night is, however, noted. Flowers were very few and could only be collected once early in the morning, showing a starch content of over 6 per cent.

As the two lucerne varieties grew in adjacent plots, and were equally watered, of equal age and were equally cut, it seems that the starch of " Provence " lucerne in the stem is more of a transitory nature than in " Hunters river." Starch is apparently formed in the flower region as well. Figures for sugars are not yet available. On the whole there is nothing unusual in the daily starch metabolism of these two lucerne varieties.

The Algerian oats offer a very different picture. Quite apart from the fact that the leaves are very poor in starch, they are lowest in daytime and increase a little during the night. The haulms, on the other hand, have a midday maximum and a midnight minimum. There are three possible explana-

tions: (a) that actually the haulms do a lot of assimilation, or (b) that the assimilation products are translocated from the leaves immediately and temporarily deposited as starch in the haulms, or (c) a combination of (a) and (b) take place. The content of cane sugar is rather high, nearly 2 per cent., whilst there is very little reducing sugar, nearly all of it fructose in samples collected in summer time.

The starch content of the two lucerne varieties during twenty-four hours agrees very well with the values obtained on fresh lucerne samples in the last 18 months. At different times strips of the well-established lucerne were allowed to wilt, then again watered to allow of recovery, the procedure repeated three to four times. Other strips were left wilting after the first drooping. Under no circumstances was the the lucerne allowed to get dry, the water loss was at the utmost 20 per cent. Other lucerne was allowed to " sweat," or to be sundried before being killed by alcohol. The result is shown in Table II. Ill-treatment of the lucerne lowers the content of starch almost immediately. The leaves are more affected than the stems. At times it appears that the temporary wilting lowers the starch content more than outright wilting. (The temporary wilting in this case means wilting from about 10 a.m. to the evening.)

Sucrose seems to be always in excess of reducing sugars. " Sweating " of lucerne, on small scale only, did not increase the sucrose content. Wilting, permanent or temporary, at times nearly doubled the content of sucrose, at other times it practically had no effect. In most cases, however, when the starch content in the wilted plants had much decreased, the content of cane sugar had increased. But in a few cases of sundried lucerne the sucrose content was high, coupled with a high starch content. The general conclusion up to now is certainly that there is not a simple relationship between wilting, disappearance of starch, and increase of cane sugar.

With regard to the reducing sugars, although they seldom reach 1·3 per cent. the variations are considerable and may be of significance as a source of fermentable material. Temporary wilting with a low starch content is often combined with a high content of reducing sugars, but not permanent wilting. On the other hand, a healthy lucerne with a high starch content can also show a high content of reducing sugars. Again the relationship does not seem to be a simple one. It seems that in all samples fructose is far in excess of glucose. In some cases, especially in " Provence " lucerne, no glucose could be traced. In some fresh " Provence " lucerne a fair amount of glucose was found. A point worth noticing is that in summer, 1942 (January-March), the sucrose content of my lucerne was much higher than in the corresponding months of 1943, although in the previous year the lucerne was rather poor, and in 1943 in beautiful condition.

The findings about sugars at first seem bewildering, as also the poisonous qualities of the plants. Is there possibly a link between these two phenomena?

There is not very much literature on the metabolism of wilted plants, yet the little is interesting enough. Some 20 years ago a Russian author, Iljin, found that photosynthesis was inhibited by wilting in all plants he examined. Respiration, however, was decreased or increased in different species. Yet the increased respiration was not regular; it dropped later, as food reserves decreased. These facts have to form the basis for our present discussion. Material for respiration are in the first line the carbohydrates. Decreased photosynthesis as well as increased respiration (which has first to be proved) accounts for the low starch values in wilted plants. It is possible that at the very start of wilting starch is dissolved and a good amount of sugar appears, but that this sugar is very quickly used up in respiration. It is not very likely that it migrates very quickly in a wilted plant, as migration is bound to free water, which is just what the plant does not have during wilting.

It may be emphasised that the present view is only a working hypothesis. Respiration experiments have to be combined with the sugar analysis and have to be extended for quite a time, to see whether, with progressive wilting, the respiration increases, and in what way the sugar content varies in this process.

The daily variations of the different sugars in fresh and wilted plants which are at present under investigation may also throw more light on the subject. Although over fifty samples have been analysed, only a few reproduced the dangerous conditions in lucerne, and many more have to be analysed before a definite statement can be made. *A priori* it seems unlikely that with an increased respiration in wilting a high sugar content is maintained for any length of time. As no new assimilation products will be produced during the wilting, the amount must be used up within a limited time, and it would not mean that each wilting or the whole wilting process would be combined with a high sugar content. There would be just a certain moment in the katabolism caused by the wilting where the polysaccharides are dissolved, and a larger amount of di- and monosaccharides are present before they are used up during respiration. If the increased content of fermentable sugars has something to do with bloating, then it would be at this particular moment.

A point to be considered as well is whether the appearance of increased amounts of sugars combined with low starch content depends on a definite water content resp. water loss of the lucerne. The water content of the plants was determined in all cases. It has first to be emphasised that the daily variations in the water content is very different in lucerne from that in Tribulus or oats. Fresh lucerne has generally over 80 per

cent. water, and wilts when a few per cent. are lost, whilst oats can show variations of 30 per cent. without any exterior sign of wilting. Tribulus behaves similarly to Gramineae. For lucerne it has been found that the highest content of sucrose is associated with a loss of $\pm 15$ per cent. water in the morning, a state found in temporary wilted and recovered lucerne. If more water is lost—which results in permanent wilting—the sugar content is again smaller. This result again seems to point to a definite physiological state in which a higher sugar content occurs.

TABLE I.

STARCH. Changes in 24 hours.

| | Date | 12 a.m. | 7 p.m. | 12 p.m. | 7 a.m. |
|---|---|---|---|---|---|
| Lucerne : | 19 20/3/43 | | | | |
| *Hunters River* | | | | | |
| Leaves ... | | 4·04 | 6·32 | 5·58 | 3·18 |
| Stems ... | | 2·00 | 2·52 | 2·25 | 2·02 |
| Lucerne · | 22 23/3/43 | | | | |
| *Provence* | | | | | |
| Leaves ... | | 7·62 | 4·91 | 3·59 | 2·54 |
| Stems ... | | 2·92 | 1·58 | 0·9 | 2·14 |
| Flowers ... | | 2·75 | 6·97 | 5·14 | 1·56 |
| Algerian Oats . | 19 20/3/43 | | | | |
| Leaves ... | | 0·55 | 0·51 | 0·74 | 0.70 |
| Haulms ... | | 2·00 | 0·74 | 0·63 | 0·90 |

TABLE II.

Changes in Starch content of Lucerne by different treatment.
(Starch in % of dry matter)

| Variety | Date | No. | Fresh | Wilted | Temporary wilted and recovered | Sweated | Poor |
|---|---|---|---|---|---|---|---|
| *Hunters River* | 12/1/42<br>13/1/42 | 2321<br>2322<br>2323 | 4·0 | — | 1 6 | — | 2·67 |
| ,, | 22/1/42 | 2324 | — | 0·59<br>8 days wilted | — | — | — |
| ,, | 25/1/43<br>27/1/43 | 2390<br>2394 | 5·11 | 2·9 | 1·85 | — | — |
| *Provence* ... | 30/1/42 | 2327<br>2328 | 4·07 | — | — | 2·77 | — |
| ,, | 27/1/43 | 2392<br>2393<br>2389 | 4·76 | 2·89 | 2·89 | — | — |
| ,, | 18/2/43 | 2419<br>2417 | 3·48 | 2·02 leaves<br>3·73 stems | — | — | — |
| ,, | 20/2/43 | 2421<br>2422 | — | — | 0·84 leaves<br>2·45 stems | — | — |

South African Journal of Science, *Vol. XL, pp. 162-163*
*November, 1943.*

# THE ALKALOIDAL CONTENT OF SOME DATURA SPECIES (STINKBLAAR).

BY
L. S. Dyson and J. A. Coetzee,
*Botany Department, University of the Witwatersrand.*

*Read 28th June, 1943.*

In this investigation, *D. Stramonium*, from Rietvlei, Transvaal and Ladybrand, O.F.S.; and *D. Tatula* from Magaliesberg and Standerton were used.

The most important alkaloid contained in stramonium is hyoscyamine, $C_{17}H_{23}NO_3$, which is converted to atrophine on heating in the presence of weak alkalis. Hyoscyamine occurs in the free condition in the plant cells and is soluble in organic solvents such as ether and chloroform. The salts of this substance are water soluble. According to the British Pharmacopœia 1932, stramonium contains not less than 0·25 per cent. of alkaloids calculated as hyoscyamine.

The drug consists of the dried leaves of *Datura Stramonium* and *Datura Tatula*. Stramonium has been known for centuries as a poison, and has been used medicinally by Natives and Europeans to relieve pain. Atropine is used in optic surgery to dilate the pupil of the eye, and also to ease respiration. This urgently required drug was obtained from Europe before the war and the supplies have now been cut off.

## Pharmacognostical Characters.

*D. Tatula* is anatomically and morphologically identical with *D. Stramonium*, but has a purple anthocyanin in the stem and flower. Some authorities regard it as a distinct species, others as a colour variety of *D. Stramonium*.

1. Two types of hairs occur on the upper and lower surfaces of the leaves, these are, however, not numerous in older leaves.
   (a) The slightly curved 3-6 celled uniserate hair with a bulbous basal cell and an acute apical cell.
   (b) The glandular type consists of a 1 or 2-celled stalk and a head of 3-6 cells. There are fewer glandular hairs than uniserate hairs.
2. The epidermal cells possess marked wavy anticlinal walls. The stomata, which occur in abundance on the lower epidermis, are characteristically bounded by cells, one of which is smaller than the rest.
3. The mesophyll is characterised by a single row of narrow palisade cells. The spongy mesophyll beneath contains numerous needle crystals of calcium oxalate, which are spherically clustered together.
4. The vascular bundles are bi-collateral.

5. The cells of the cortical parenchyma and pith are typically large.

## COLLECTION, DRYING AND ASSAY.

The leaves are collected at the flowering period and dried without the application of heat or exposure to sunlight until the moisture content is about 10 per cent.

Full particulars of the method of extracting and estimating the alkaloids are given in the British Pharmacopœia, 1932.

Experience gained during the assay showed that variations in procedure to a certain extent influenced the results. The most important points are as follows:—

1. At certain stages of the assay the solutions have to be agitated. The solutions should be shaken as thoroughly as possible to ensure complete reactions. Emulsions are apparently not formed in this material.

2. When the acid solution containing water soluble salts of the alkaloid is made alkaline, the salts are broken up and the alkaloids are liberated directly. The chloroform in which the alkaloids are then dissolved should be added immediately to ensure complete extraction of alkaloid from the alkaline solution.

3. After the alkaloidal residue of the extract has been dissolved in 20 mil. of N/50 $H_2SO_4$, the liquid is conveniently transferred to a 100 mil. standard flask and made up to volume. Aliquots of 20 mil. are titrated against N/50 NaOH advantageously, using a microburette.

4. If the N/50 acid solution (referred to under 3) containing the alkaloid is not clear, i.e., if it contains undissoved particles, the solution must be well shaken and left standing for a day or two so that all the alkaloid present in these particles can react with the acid.

5. Difficulty may be encountered when using methyl red as indicator in the titration, since some of the extracts have a yellowish orange coloration. In such case the use of litmus is advisable.

## RESULTS.

Two samples of *Datura Stramonium* and two samples of *Datura Tatula* were analysed. The results were as follows:—

*Percentage of Hyoscyamine.*

1. *Datura Stramonium* cultivated at Rietvlei: 0·25 per cent.
2. *Datura Stramonium* uncultivated at Ladybrand: 0·21 per cent.
3. *Datura Tatula* uncultivated at Magaliesberg: 0·24 per cent.
4. *Datura Tatula* uncultivated at Standerton: 0·16 per cent.

As will be seen, the alkaloidal content of the cultivated sample of *Datura Stramonium* from Rietvlei, was higher than that of the uncultivated sample from Ladybrand. J. McNair. 1941, found that nitrogenous fertilizers, such as farmyard manure and sodium nitrate, increase the toxicity of *Datura Stramonium*. The differences in the alkaloidal content between the two varieties of *Datura* are merely of the same magnitude as variations within one and the same variety.

South African Journal of Science, *Vol. XL, pp. 164-195, November, 1943.*

# THE CRANIAL AND VISCERAL OSTEOLOGY OF THE NEOTROPICAL ANURAN *BRACHYCEPHALUS EPHIPPIUM* SPIX.

BY

P. McLachlan,

*Zoological Institute, University of Stellenbosch.*

*With 9 Text-Figures.*

*Read 29th June, 1943.*

## Introduction.

Duméril and Bibron, 1841 ([19]) state that in 1824, Spix described a certain frog as *Bufo ephippium*, but in 1826, Fitzinger removed this species from the genus *Bufo* and created a new genus, *Brachycephalus*, for its reception; that in 1835, Cocteau changed the generic name to *Ephippipher* and erroneously created two species; and that in 1838 Tschudi returned to Fitzinger's nomenclature. This has been accepted by all subsequent authors. The genus *Brachycephalus* was included in the family " *Bufoniformes* " by Duméril and Bibron (1841). Gunther ([26]), however, established the family *Brachycephalidæ* which included three genera: *Pseudophryne*, *Brachycephalus* and *Hemisus*. Boulenger ([1]) did not accept the validity of this family and included *Brachycephalus* and *Hemisus* in the *Engystomatidæ*, whereas *Pseudophryne* was referred to the *Bufonidæ*. This classification of *Brachycephalus* was retained by Gadow ([22]), Boulenger ([5]) and Nieden ([29]). De Miranda-Ribeiro ([7]) in his monograph on the *Anura* of Brazil recreated the family *Brachycephalidæ* for the reception of the genera *Brachycephalus* and *Atelopus*. Noble ([30]) accepted this family, but expanded it to include a large group of small neotropical toads. The family as defined by Noble is composed of three sub-families, the *Rhinodermatinæ*, the *Dendrobatinæ* and the *Brachycephalinæ*, each of which, according to him, has arisen from a different stock of Bufonids all of which, however, resided in the same general area. He, therefore, considers the *Brachycephalidæ* a natural, even though a composite family and defines it as: " Procoela with the two halves of the pectoral girdle partly or wholly fused in the midline " (op.cit., p.505).

As the above-mentioned descriptions of the genus are chiefly of a systematic nature they refer to external cranial features only. Chief among these are: the absence of palatal folds, the absence of vomerine, maxillary and premaxillary teeth, the circular choanae, the horizontal pupil, the fact that the

skin over the tympanum is not differentiated, the absence of the middle ear and the rudimentary nature of the Eustachian tubes (the last statement, however, is incorrect). Reference is also made to the secondary dermal ossifications fused to the neural spines of the second to the seventh vertebrae. Duméril and Bibron ([19]) erroneously regarded these dorsal shields as the fused dilated ends of the neural spines. Evidently these were the only investigators to notice the similarity in appearance between the dorsal bony shields and the roof of the skull, an observation which led them to suggest that the dorsal and lateral surfaces of the skull are protected by a carapace similar to that on the back.

## Material and Technique.

Specimens of *Brachycephalus ephippium* were collected at Petropolis, Brazil, by the late Dr. A. Lutz and presented to the Zoological Institute of the University of Stellenbosch by his daughter, Dr. Bertha Lutz, to whom we wish to express our sincere thanks. After the legs, arms and lenses were removed, two specimens measuring respectively 22 mm. and 16·2 mm. from snout to vent were decalcified in $HNO_3$—alcohol, (7·5 ml. $HNO_3$ in 100 ml. 60 per cent. alcohol). The acid was removed by placing the objects in 5 per cent. solution of $Na_2SO_4$, after which they were washed in tapwater. The specimens were bulk-stained in borax carmine, embedded and the entire bodies microtomised at 20μ and 10μ respectively. The sections were counterstained in Azan solution as supplied by Grübler. For the preparation of the graphical reconstructions, drawings made with the aid of the Panphot microscope were projected onto graphed paper ruled in millimetres.

## The Olfactory Capsule.

The structure of the olfactory capsules shows very little resemblance to that of most other *Anura* hitherto investigated. The capsules are especially characterised by the wide divergence of their anterior portions which reach well beyond the septum (Fig. 1), and by more extensive and intensive ossification than that occurring in any other known Anuran.

An anterior wall in the Gauppian sense is absent, since the anterior tip of each nasal capsule, in this region occupied by the cavum principale only, tapers to a blunt point capped by the alary cartilage. The superior prenasal cartilage is a comparatively large medial appendage of the alary stretching from the dorsal portion of its median convex surface in a postero-ventral direction. It is attached to the alary by means of feeble chondrosis. The cartilage supports the facial part of the premaxillary as in *Rana* (Fig. 2).

The shape and relations of the inferior prenasal cartilage do not deviate from those obtaining in *Rana*.

The oblique cartilage is Ranid, except that shortly anterior to the planum terminale its external surface is incompletely

covered by the downward sloping lateral wing of the bony nasal roof, most likely of the nasal bone itself. The slit between the bone and the cartilage serves for the transmission of the ramus lateralis narium (Fig. 3).

The crescent-shaped alary is particularly large and occupies a position completely different from that in almost all other *Anura*. It resembles an inverted Ranid alary, its concave surface facing laterally instead of medially, in this way supplying a medial wall to the anterior part of the capsule. When examining the sections successively from the anterior end one observes that the cartilage increases dorso-ventrally and medio-laterally so that it forms a ventral and medial support for the vestibule and for the anterior part of the cavum principale (Fig. 2a). The external narial aperture which faces antero-laterally is, therefore, bounded dorsally by the tectum and ventrally by the lateral margin of the alary.

The tectum appears in section, dorsal to and a short distance behind the anterior limits of the alary, enlarging posteriorly into a curved bone forming the dorso-lateral roof of the anterior part of the cavum principale. In the region immediately behind the external narial aperture the alary reaches its maximal dimensions and enters into a medio-dorsal synchondrotic union with the tectum (Fig. 2a). This connexion is soon severed and the posterior part of the alary is reduced to a small, laterally compressed cartilage having a slightly concave lateral surface. It still participates in the formation of the medial wall of the nasal capsule (Figs. 2b and c).

Posteriorly the crista intermedia, with which in this region solar elements may already be fused, substitutes for the alary as medial wall of the capsule. It arises anteriorly to the fenestra nasobasalis from the tectum of the preseptal region, whereas in *Rana* it arises dorsally to the fenestra nasobasilis from the anterior part of the tectum adjoining the septum. Its more anterior position in *Brachycephalus* is evidently due to its serving as a medial wall for the capsule in the preseptal region. The crista intermedia is partially calcified and ossified and is directly continuous with the lamina superior and with the anterior part of the lamina inferior.

The crista subnasalis is not a ventro-medially flexed process of the solum, but appears merely as an extension of its antero-lateral part. It is comparatively long, projecting forwards and slightly downwards, reaching to a point beyond the anterior limits of the superior prenasal cartilage. It should be noted that the functional floor of the capsule is not homologous in all forms. In the region where the alary has shifted from a ventro-medial into a medial position, the underlying crista subnasalis forms for a short distance the nasal floor (Fig. 2b). In this region the anterior limits of the lamina superior and of the lamina inferior are incorporated in the crista subnasalis, since in the sections immediately following, the floor is differentiated

into two horizontal cartilaginous blades of which the upper is the lamina superior and the lower the completely fused lamina inferior and solum (Fig. 2c). The anterior part of the cavum medium is lodged between these blades. From recent investigations (in progress) Dr. C. A. du Toit concludes that a fusion of the lateral parts of the lamina inferior and of the solum as occurring in *Arthroleptides* and others, is to be regarded as a neotenic condition. In the light of these conclusions the complete fusion of the structures concerned in *Brachycephalus* is, therefore, a very marked neotenic phenomenon.

At first glance it would appear that the lamina inferior and the crista intermedia are absent: the lamina superior being directly attached to the solum. A careful study, however, reveals that this unique condition is due to the complete fusion of the lamina inferior and the posterior part of the crista intermedia with the underlying solum, the whole presenting itself as an upwardly and inwardly sloping plate medio-dorsally confluent with the preseptal part of the tectum. Accordingly the cavum inferius normally covered dorsally by the lamina inferior and the crista intermedia and ventrally by the solum, lacks a similar skeletal support in *Brachycephalus*. The medial portion of the inwardly sloping plate is well ossified (Figs. 3a and 3b).

A fusion of the crista intermedia and the solum also occurs in *Callulina* [19], but it seems to be less intimate than in *Brachycephalus*. The above-mentioned fusion and extensive ossification rendering the skull more rigid is undoubtedly an adaptation to a fossorial mode of life.

The appearance in section of the fenestra nasobasalis is accompanied by a bifurcation of the bone representing the fused solum and crista intermedia. The medial of the two limbs thus formed is continued posteriorly as the solum, to which the inferior prenasal cartilage becomes attached, whereas the lateral limb, representing the crista intermedia, disappears from section (Fig. 3c). This bifurcation, therefore, indicates the separation of the solum and the crista intermedia as well as the posterior termination of the latter, so that the fenestra nasobasalis may be described as a paraseptally situated fenestra piercing the solum immediately behind the crista intermedia.

The lamina superior is a more or less rectangular blade attached medially to the median part of the lamina inferior and to the crista intermedia anteriorly to the crista subnasalis, whereas its posterior and its lateral margin are free. The latter is anteriorly invested by the septomaxillary (Fig. 2c). Posterior to the septomaxillary the infundibulum passes over the free lateral edge of the lamina superior to communicate with the cavum medium (Fig. 3a).

At the anterior border of the fenestra choanalis the lamina inferior and the solum are separated from each other, since at this niveau the former is reduced to a laterally situated cartilage,

fused with the planum terminale, wheras the solum is continued backwards.

Its lateral edge constitutes the medial border of the fenestra choanalis. Since the cavum inferius cannot occupy its normal position between the lamina inferior and the solum, it must necessarily occupy a markedly posterior position, being situated at the niveau of the fenestra choanalis and immediately behind the cavum medium. The fenestra choanalis accordingly affords exit to the anterior part of the recessus lateralis which then receives its main support from the frontal and palatal parts of the maxillary (Fig. 4a).

The planum terminale fuses with the dorsally flexed lateral margin of the lamina inferior, whereupon the fused cartilages are continued posteriorly as a sagittally situated strip, of which the dorsal edge becomes confluent with the lower margin of the ventrally projecting bony lateral wing of the roof (Fig. 4). Sections from the less strongly ossified specimen reveal that this confluency actually occurs only with the tectal component of the roof. If, therefore, the tectum were to remain cartilaginous and free from the overlying bone, the dorso-lateral side of the cartilaginous nasal roof would reveal a fenestra bounded laterally by the oblique cartilage and the planum terminale. Similar conditions were described for *Breviceps* ([12]), *Probreviceps* ([14]), *Spelæophryne* ([18]) and *Callulina kreffti* ([39]). Topographically this fenestra resembles the fenestra dorsalis of the Urodelan skull.

The sagittal cartilage maintaining its confluency with the bony roof is continued posteriorly and ultimately passes over into the planum antorbitale, in this way forming a lateral margin for the fenestra choanalis (Fig. 1). At the same time it forms a lateral support for the weakly differentiated plica isthmi so that the cartilage resembles a processus lingularis of which the posterior limit is confluent with the planum antorbitale.

In the less strongly ossified specimen the cartilage of the antorbital process is pierced immediately ventral to the foramen for the ramus orbitonasalis, by a small fenestra covered by tubules of the Harderian gland. Apparently it does not serve any particular function, and the absence of a similar fenestra in the other specimen must be ascribed to the occurrence of secondary dermal ossification in the antorbital region.

The septum is completely ossified and as far forward as the fenestra nasobasalis the ossification extends into the solum although the latter becomes completely ossified only in the prechoanal region (Fig. 1). A somewhat similar ethmoidal solar ossification occurs in *Hemisus* ([9]) and *Elosia* ([45]).

An eminentia olfactoria as such cannot be distinguished. Anteriorly to the choana a small cartilaginous process is attached to the lateral margin of the ossified solum (Fig. 1). This process projects into the fenestra choanalis, supporting, but not invaginating the floor of the cavum principale. The process,

however, is not elevated and the overlying epithelium is actually thinner than that of the roof and floor of the anterior part of the cavum principale, so that it is doubtful whether this part of the solum is at all related to a specialised eminentia olfactoria. Since Ramaswami ([37]) has described an elevated eminentia in completely aquatic forms such as *Rana hexadactyla* and *R. cyanophlyctis*, this condition for a form so terrestrial as *Brachycephalus* is, therefore, a further refutation of the theory previously put forward by de Villiers ([14]) and Helling ([27]) that a pronounced elevation of the eminentia, as seen in the *Bufonidæ*, *Ranidæ* and *Microhylidæ* is closely correlated with the fossorial mode of existence.

### The Membrane Bones of the Nasal Region.

The maxillary, the premaxillary and the septomaxillary are the only membrane bones to be distinguished as such, the others being absent or incorporated in the extensive ethmoidal ossifications.

Practically the whole of the nasal capsule is covered both dorsally and laterally by a massive bony roof provided with marrow cavities and in which the following structures are most probably incorporated: ossified tectum, os en ceinture, nasals, anterior portions of the frontoparietals, together with a varying amount of secondary dermal ossification. In this respect *Brachycephalus* somewhat resembles the adult *Hemisus* ([9]) in which the chondrocranium is extensively ossified and fused with the covering dermal bones. The secondary dermal ossification occurring in the cranial region proves to be identical with that over the back of the animal. Further reference to this will be made later.

A more exact determination of the components of the bony roof is rendered possible by an examination of the skull of the specimen in which the cartilage and cutis are less strongly ossified. The nasal bone investing the cartilaginous tectum is identifiable at the level of the choana.

Corresponding to the capsules the bony nasal roof likewise divides anteriorly into two divergent squames each partly overlying the preseptal portion of the capsule (Fig. 1). The anterior part of the tectum remains cartilaginous and is overlain by the bony roof, but more posteriorly it ossifies and fuses with the latter. Judging from its topographical position this part of the roof is the anterior part of the nasal (Fig. 2).

A fairly deep, broad median groove passing anteriorly into the space between the two separated capsules, characterises that part of the roof above the anterior end of the septum. It is occupied by tubules of the intermaxillary gland. This groove may have resulted from the separation of the divergent squames of the roof occurring more posteriorly than the point of separation of the capsules, so that the dorsal surface of the septum actually constitutes the floor of the groove (Fig. 1 and

Fig. 3). A definite solution is, however, impossible owing to the bony continuity of the roof with the septal ossification.

The external surface of the nasal roof is characterised by numerous bony asperities. The studded appearance of the roof is due to its fusion with numerous separate ossicles arising in the overlying cutis fibres as a result of secondary dermal ossification. The nasal is apparently of a similar nature in *Scaphiopus holbrookii* and *S. solitarius* ([35]) and in *Calyptocephalus* ([38]). In the specimen of *Brachycephalus* in which the cutis is less ossified the nasal exhibits a smooth surface. There is no contiguity between the frontal process of the maxillary and the nasal.

Since there is no trace in the adult of the vomer or of the palatine, developmental stages will have to be investigated with a view to determining whether these bones are altogether absent or are reduced and incorporated into neighbouring structures. Somewhat similar conditions obtain in *Hemisus*, but de Villiers ([9]) found that the remains of the nasals and of the vomers could be located in a juvenile, but that the palatine was absent. The os en ceinture invades to a marked degree the cartilage of the processus antorbitalis so that the latter may functionally replace the palatine. Similar conditions accompanied by the absence of the palatine obtain in *Scaphiopus holbrookii* and *Megophrys major* ([35]). Ramaswami, however, points out that the absence of the palatine cannot be correlated with the ossifications of the antorbital region, as the bone is also wanting in species of *Microhyla* even though the antorbital process is not ossified.

The septomaxillary assumes the form of a thin vertical column on a pedestal broadening out anteriorly, medially and posteriorly. The vertical column supports the lateral wall of the anterior part of the infundibulum. The pedestal rests upon the dorsally flexed lateral margin of the lamina inferior, while its medial extension invests the anterior part of the lateral edge of the lamina superior (Fig. 2c). The relation between the bone and the cartilage is very intimate, so that practically all traces of intervening connective tissue have disappeared. This is particularly noticeable between the septomaxillary and the calcified lateral edge of the lamina superior. It is remarkable that the bone bears no relation to the ductus nasolacrimalis as it does in *Rana* and most *Anura*. It disappears from section well in front of the region where the duct passes out of the cavum medium.

Both the maxillary and the premaxillary are edentulous. The latter is characterised by a very large horizontal plate reaching anteriorly far beyond any other skeletal part of the snout, and resembling a large palatal squame projecting forward from the facial part of the premaxillary (Fig. 1). A structure similar to this anterior squame has not been described in other *Anura*; it is most probably a secondary adaptation to the

fossorial mode of life. The rest of the premaxillary is Ranid in structure as are also its relations to neighbouring skeletal parts.

The anterior process of the maxillary reaches very far forward, but the premaxillary even farther so; this condition is presumably to be interpreted as an adaptation to fossorial life.

### The Sphenethmoid Region.

It is impossible to determine the anterior or posterior limits of the os en ceinture since it is in entire bony continuity with the adjoining parts of the skull. The posterior portions of the nasal cavities reach backward beyond and below the anterior limits of the brain cavity, so that the olfactory nerves enter the olfactory capsules dorso-medially. Similar conditions obtain in *Elachistocleis ovalis* [31] and *Microhyla carolinensis* [40].

In the less extensively ossified skull the anterior part of the fused frontoparietals is separated from the os en ceinture by intervening connective tissue, but in the other specimen the two structures are inseparably fused with each other, so that a section of the sphenethmoid region presents a complete bony ring.

### The Orbital, Otic and Occipital Regions.

Medially the frontoparietals are in bony continuity with each other and laterally with the ossified side walls of the cranial cavity. The cranial floor is likewise completely ossified, so that throughout the sphenethmoid and orbital regions the neurocranium appears in section as a complete bony ring. Medial fusion of the frontoparietals also occurs in *Hemisus*, [9] *Philantus petersi* [37], *Nectophryne misera* [36] and *Elosia nasus* [45], although in *Elosia*, and evidently in *Philantus* and *Nectophryne* as well, the bones are not fused throughout their entire length, so that they include a fontanelle between them. The anterior and posterior limits of the frontoparietal bone cannot be located, since the bone is confluent with the osseous roofs of the nose and of the otic and occipital regions. Accordingly we arrive at the singular condition in which practically the entire skull is roofed by one complete bony structure, composed of different elements and devoid of any fontanelles. In the less ossified skull the anterior tips of the fused frontoparietals overlap onto the sphenethmoid region and are separated from the nasal roof and the os en ceinture by connective tissue. Bony asperities, similar to those of the nasal roof also characterise the roof of the orbital and occipital regions.

In the region of the otic capsule, a well-developed downward sloping wing of dermal ossification extends from the roof of the skull and overhangs the capsule. Posteriorly this overhanging bone becomes a massive structure attached to the lateral wall of the auditory capsule, and is provided with large marrow cavities (Figs. 5, 6 and 7). Its connexion with the skull is severed at the level of the jugular foramen only. The structure is continued posteriorly, disappearing from section together with the condyles.

Since a cartilaginous tectum synoticum cannot be distinguished, it is possibly ossified and fused with the overlying and adjacent bones. There is no trace of either the tænia tecti transversalis or the tænia tecti medialis. As the development of the skull is not known, it is impossible to determine whether the cartilages are not represented, as is very often the case, or whether the bone arising from them is incorporated in the neighbouring ossifications. Ossification of the tæniæ and subsequent fusion with the frontoparietals occur in *Elosia nasus* (45), whereas incipient enchondral ossification of the tænia tecti medialis is described for *Arthroleptella* (8) and *Anhydrophryne* (11). Pentz (31) points out that the theory of some authors that the tænia tecti transversalis, when lacking, has been incorporated in the tectum synoticum appears unlikely, since de Beer (1937, p.204) has shown that in *Rana* the tænia tecti transversalis originates from a median unpaired chondrification which interconnects the two pilæ antoticæ. From the above it is clear that the homology of the "dorsal fenestra" cannot be established in *Brachycephalus*.

The parasphenoid, although fused to the ossified cranial floor, can, however, at intervals be distinguished as such by its more intensive ossification. In the less ossified skull, in which the cranial floor is only perichondrally ossified, the bone can be more definitely located. It is typically dagger-shaped, the lateral wings supporting the auditory capsules.

The foramina of the orbito-temporal region show no significant divergences from the Ranid condition, except that they are all surrounded by bone.

The otic capsule is intensively and extensively ossified as in *Hemisus* (9) and *Elosia* (15). The pro-otic is ankylosed to the exoccipital, presumably by the ossification of the cartilago pro-otico-occipitalis, so that mutual boundaries cannot be determined. In the less ossified specimen, traces of the latter can be located as perichondrally ossified cartilage. The septum between the capsule and the brain cavity is also ossified, although small patches of residual cartilage occur (Fig. 5).

The endolymphatic foramen is situated above and in a line midway between the two foramina acustica, all of them being surrounded by bone. Large marrow cavities are plentiful in the ventrolateral wall of the capsule (Figs. 5, 6 and 7). The well-developed lower ledge of the fenestra ovalis as well as a part of the capsular floor at the pseudobasal articulation remains cartilaginous (Figs. 5b and 6).

In both specimens examined there is only one large perilymphatic foramen of which the posterior part is somewhat ventrally disposed, opening into the anterior part of the jugular fissure. The latter occupies the normal position postero-ventral to the otic capsule. A single perilymphatic foramen is the normal condition in the *Gymnophiona* and in the *Urodela*, but a unique feature among the *Anura*.

The region of the fenestra ovalis has an extraordinary appearance in section, due to the extreme development of its cartilaginous lower margin, of which the lateral edge is dorsally flexed, so that a particularly large and deep fossa fenestræ ovalis is formed (Fig. 6). Anteriorly the dorsally flexed portion of the ledge is actually confluent with the anterior and antero-dorsal margins of the fenestra ovalis, so that the anterior part of the fossa fenestra ovalis is transformed into an extra-capsular cavity into which the anterior part of the fenestra ovalis opens.

### The Auditory Skeleton.

As in *Ascaphus* (16), *Liopelma* (16), *Bombina* (16) and *Hemisus* (9), the middle ear, tympanic membrane, annulus tympanicus, Eustachian tubes and plectral apparatus are absent, an operculum, however, being present. In *Cacosternum namaquense* (16) similar conditions obtain, except that the Eustachian tubes are present.

The operculum is markedly well-developed, remains cartilaginous and occupies most of the space of the fossa fenestræ ovalis. Its anterior portion projects a short distance into the extracapsular cavity (Fig. 6b and c) and as in the *Liopelmidae* (16) the operculum does not fill the anterior part of the fenestra ovalis. This part of the operculum is medially concave and saucer-shaped, whereas posteriorly it assumes the shape of a tapering rod reaching backwards beyond the jugular foramen. Owing to the indifferent state of preservation of the epithelium it was impossible to trace the extent of the ductus fenestræ vestibuli. The operculum is in synchondrotic continuity with the postero-dorsal rim of the fenestra ovalis (Fig. 6d) and for some distance behind the fenestra with the otic capsule.

As in *Hemisus* (9), *Ascaphus* (16), *Liopelma* (16), *Spelaeophryne* (18) and *Elachistocleis* (31) the musculus levator scapulæ superior is opercularised, a condition which would, according to de Villiers (9), indicate increased terrestrialisation. The muscle is attached to the posteriorly directed rod-like portion of the operculum, so that the latter apparently corresponds to the lateral knob developed in other forms for the attachment of this muscle. There is no encroachment of the scapular region onto the otico-occipital portion of the skull as in *Hemisus* (9), *Ascaphus* (16) and *Bombina* (46). De Villiers (9) suggests that this peculiarity of these genera " is probably due to the need of proximity between the suprascapula + cleithrum and the operculum, so that the sound may be conducted along the shortest possible route on its way to the operculum." (p.324.) Perhaps this need of proximity between the scapula and the operculum necessitated the marked posterior extension of the operculum in *Brachycephalus*.

### The Palatoquadrate and the Suspensorial Region.

As in *Spelaeophryne* (18) and *Callulina* (37) the maxillary is a short bone investing only the anterior part of the pterygoid

process laterally, and not extending posteriorly beyond the optic foramen, so that the subocular arch largely consists of the pterygoid process and the pterygoid. The bone separates from the pterygoid process in the region of the angle of the mouth and terminates posteriorly as a tiny splint-like process under the skin, lateral to the masticatory muscles.

Up to the oral angle the pterygoid appears in section as a small dorsal investment of the pterygoid process, and where the latter merges into the quadrate process the pterygoid shifts from a dorsal to a medial position (Fig. 5a and b). In this region the connective tissue separating the bone and the cartilage disappears so that the pterygoid simulates perichondral ossification of the quadrate cartilage. Towards the articular region the bone is fused to the perichondral and enchondral quadrate ossifications.

As in *Hemisus* (9), *Ascaphus* (16), *Liopelma* (46), *Spelaeophryne* (18), *Breviceps* and *Probreviceps* (14) and *Callulina* (39), the quadratomaxillary (=quadratojugale) cannot be located. In the *Liopelmidæ* and in *Brachycephalus* the pterygoid and the paraquadrate do not fuse, as they do in the other cases in which the quadratomaxillary is absent, so that it is doubtful whether the fusion of these bones is to be associated with the absence of the quadratomaxillary as was suggested by de Villiers (14). Roux states that it is possible that the quadratomaxillary may actually be present in *Callulina*, but that it is fused with the ventral part of the paraquadrate as in some specimens of *Rana grayi* (20). Should such a fusion occur, it is clear that the quadratomaxillary can easily be overlooked, especially when it is not produced forwards beyond the paraquadrate. Thus de Villiers (17) points out that although it has been generally assumed that gymnokrotaphic *Urodeles* such as *Ambystoma* and *Hynobius*, lack a quadratomaxillary, they actually possess the bone and that it bears the same topographical relations to the pars quadrata and to the paraquadrate as in *Anura*, but that it is not produced forwards in the direction of the maxillary. It would, therefore, perhaps be wiser to consider developmental data as essential before making any definite statement as to the absence of the quadratomaxillary. In *Hypogeophis*, de Villiers (17), working upon Prof. Marcus's material demonstrated the presence of the bone in developmental forms.

The most striking feature of the pars quadrata and its relations to the skull is the absence of the otic process and of the crista parotica. In the less ossified specimen there occurs immediately antero-dorsal to the pseudobasal articulation a well-developed syndesmotic connection between the otic capsule and the paraquadrate, whereas in the other specimen the connective tissue stretches between the capsule and that part of the paraquadrate invading the antero-dorsal part of the pars quadrata. In both specimens the distal attachment of the connective tissue is situated in the region where the two posterior

rays of the paraquadrate meet (Fig. 5a and b). It would appear that since the paraquadrate and the quadrate are intimately united, the connection has a suspensorial function, even if the connective tissue is not attached to the pars quadrata itself. The absence of the otic process and of the crista parotica is an extremely rare feature among the *Anura*, the only other instance described in which similar conditions obtain being *Acris gryllus*, referred to by Stadtmüller ([43]). Here too, a syndesmotic connection is said to exist between the quadrate and the otic capsule.

The pseudobasal process is well-developed and remains cartilaginous, except for small patches of perichondral bone probably representing isolated parts of the pterygoid. It articulates over a broad surface with the otic capsule (Fig. 5b) and is in synchondrotic union with the cornu hyale.

The pars quadrata is intensely ossified, largely owing to the marked invasions of the pterygoid and especially of the paraquadrate. Subosseous excavations of the cartilage appear in the anterior parts (Fig. 5b); towards the articular region the quadrate cartilage shows a perichondral bony margin and a large central marrow cavity completely lined by enchondral bone (Fig. 7). The extreme tip consists exclusively of cartilage. Similar conditions obtain in the pars quadrata of *Hemisus* ([9]). It has been assumed that in the majority of the *Anura* the ossification of the quadrate cartilage is initiated by the quadratomaxillary, an assumption which seems to be borne out by the fact that in forms like *Breviceps* ([14]), *Spelaeophryne* ([18]) and *Callulina* ([39]) which lack a quadratomaxillary, the quadrate cartilage remains unossified. De Villiers ([17]), however, rightly points out that he is not confident about the possibility of proving that the ossification of the pars quadrata is not autochthonous. In his work on *Cacosternum* ([13]) he describes a condition in which the pars quadrata is unossified although the quadratomaxillary is, histologically speaking, in an advantageous position to cause enchondral ossification of the cartilage invested, whereas in *Ascaphus* ([16]) and in *Liopelma* ([16]), both of which lack a quadratomaxillary, a genuine os quadratum is present. In *Hemisus* ([9]) and in *Brachycephalus*, a true quadrate bone probably exists together with the ossifications from the paraquadrate and the pterygoid.

The paraquadrate of Gaupp (= squamosal auctorum) is a large triradiate bone. Its anteriorly projecting zygomatic process is the smallest of the three rays and is surrounded by masticatory muscles, some of which are attached to it. Of the two posterior rays the particularly large lower one is intimately fused onto the pars quadrata, whereas the upper, in the absence of the crista parotica projects freely in a postero-dorsal direction. Its distal end is lodged between the outer wall of the otic capsule and the overhanging wing of dermal ossification (Fig. 7). Large masticatory muscles extend between this process and the Meckelian cartilage.

### THE LOWER JAW.

The infrarostral portion of Meckel's cartilage is calcified, but not enchondrally ossified. The perichondral ossification, the mentomandibular, is fused to the dentary. The symphysial cartilage is also calcified so that it has presumably lost much of its elasticity. The rest of the lower jaw conforms to the Ranid type.

### THE HYOID APPARATUS.

The structure of the hyoid apparatus deviates considerably from that of the typical Ranid condition as described by Gaupp (1896).

The corpus hyoideum is of a narrow, elongated shape, its length being slightly greater than twice its least width. The processûs anteriores are particularly long and straight with their anterior tips turned slightly inwards. This marked development of the anterior processes does not correspond to the condition in the other genera (*Dendrophryniscus*, *Oreophrynella* and *Atelopus*) of Noble's subfamily, *Brachycephalinæ*, in which these processes are absent in the species described by Trewavas ([11]) and by Badenhorst ([1]). (Only in the case of *Atelopus ignescens* Trewavas describes a small anterior process which may form a loop by fusion with the hyale.) Summing up her observations on the hyolaryngeal structure of the *Brachycephalidæ*, Trewavas states (p.517): "In sum, a knowledge of the hyolaryngeal apparatus of five genera of the eight in Noble's *Brachycephalidæ*, makes doubtful any special relationship between *Brachycephalus* on the one hand and *Dendrophryniscus*, *Oreophrynella* and *Atelopus* on the other." It might be mentioned here that the hyoid apparatus of the *Dendrophryniscus* group is very similar to that of *Bufo*, in which the anterior processes are usually also missing.

The opinion has been expressed that the phylogenetic importance of the processus anterior is negligible, since the structure is particularly subject to modification: Striking variations occurring even in members of the same genus or species ([11]). This, however, concerns variations in shape and structure of the process, not its presence or absence.

The alary and especially the postero-lateral process are much reduced, both appearing merely as laterally extended margins of the corpus. The complete absence, or highly reduced state of the postero-lateral process is common to all the species of *Brachycephalinæ* described by Trewavas, as well as to *Atelopus moreiræ* ([1]).

The dorsally flexed processûs thyreoidei (postero-medial) diverge very widely from each other. They are completely ossified perichondrally, except for small cartilaginous distal epiphyses. As a result of the wide divergence of these processes, which may be ascribed to the shortness of the skull, the larynx not only extends posteriorly well beyond the thyroid processes,

but its anterior portion overlies the posterior border of the corpus hyoideum.

Each cornu principale is a slender cartilaginous rod extending latero-posteriorly, then curving round antero-dorsally and becoming confluent with the pseudobasal process of the palato-quadrate, where the latter articulates with the otic capsule. Similar conditions obtain in *Atelopus moreiræ* (1) and in *Microbatrachella* (15).

### THE CARTILAGINOUS LARYNX.

The dorso-ventral axis of the arytænoids and of the cricoid is nearly vertical, differing from the typical condition, in which the axis slants dorsally backwards. The arytænoids form a broad, flat dome, situated between the widely separated postero-medial processes of the hyoid. Their inner surfaces are smoothly concave, corresponding to the convex contour of the outer surfaces. From each arytænoid a single short apex (prominentia apicalis) projects anteriorly and slightly upwards. In *Rana esculenta*, Gaupp (24) describes a prominentia dorsalis and a prominentia ventralis bounding an incisura apicalis between them, the latter containing a small separate conical cartilago apicalis, which Blume (2), however, proved to be a prominentia intermedia of the arytænoid. It is difficult to homologise the single apex in *Brachycephalus* with one or more of the three prominentiæ mentioned above. A separate minute cartilage in the apical zone of the arytænoid (cartilago Santorini of Blume) is not present. A wide gap formed between the dorsal ends of the arytænoids is almost completely bridged by large dorsal pulvinaria vocalia so characteristic of the Ranids. The ventral pulvinaria are smaller. In the basal rim of the arytænoid, a wide incision situated towards the dorsal side resembles the incisura articularis which Blume describes for species of *Bufo*.

The cricoid (cartilago crico-trachealis of Gaupp) forms a complete, more or less elliptical ring, of which the ventral portion passes to the inside of the corresponding basal rim of the arytænoid dome. Of the three Gauppian processes (pr. articularis posterior, pr. articularis anterior and pr. muscularis) of the pars cricoidea of the cricoid, it was not possible to distinguish the anterior one in the material examined. Trewavas (11) describes all three processes in *Brachycephalus ephippium*. The connection between the arytænoids and the cricoid is syndesmotic. The lateral arcs of the cricoid ring has a marked lateral extension (thus conditioning the elliptic shape of the ring) to form the tubercula hyoidea (Blume's nomenclature) for the attachment of the ligamentum hyocricoideum. These tubercula are not contiguous with, or in close proximity to the thyroid processes of the hyoid, but a well-developed ligamentous hyocricoid union is established by means of the hyocricoid ligament, which is attached to the cartilaginous distal end of the thyroid process (Fig. 9). Trewavas describes the hyocricoid union of *Brachy-*

*cephalus ephippium* as being intimate and of a unique type, consisting of a spoon-shaped lateral process of the cricoid, fitting over the end of the thyroid process.

The spina œsophagea of the cricoid is of moderate length, but the bronchial process (processus trachealis + processus pulmonalis of Gaupp) is absent. Here too, our observations differ from those of Trewavas, who describes the bronchial process as being represented by a minute vestige on one side of the cricoid.

The cartilago basalis is absent.

## Discussion.

Some features of the cranial anatomy of *Brachycephalus* merit further discussion.

(a) It is remarkable that the greater part of the olfactory capsule appears in section before the septum. It may be well to recapitulate the structures situated in the preseptal portion of the capsule: superior and inferior prenasal cartilages, alary, oblique cartilage, cartilaginous part of the tectum, lamina superior, crista intermedia, crista subnasalis, septomaxillary, premaxillary, external narial aperture, as well as the anterior portions of the lamina inferior, solum, maxillary, nasal, cavum principale and cavum medium. The separated condition of the nasal capsules in the preseptal region, also obtaining to a less pronounced extent in *Elachistocleis* [31] is strikingly reminiscent both of the nasal capsules of *Urodela* as well as those of larval *Anura*. Describing the development of the chondrocranium of *Ambystoma*, de Beer (1937, p.180) states: " An important feature is the fact that each nasal capsule is completely separate from the other and has its own medial wall, for there is no nasal septum, its place being taken by the cavum internasale." Dealing with the development of the chondrocranium in *Rana fusca*, de Beer writes: " Dorsally the hind end of the nasal septum is continued on each side into the flat roof of the nasal capsule or tectum nasi. This grows forwards somewhat independently of the septum, so that anteriorly on each side a sort of cupola is formed with its own medial wall which then becomes attached to the septum. This point is of importance for the comparison between *Anura* and *Urodela*. . . . .It is clear that the nasal capsule of the frog (and of *Anura* generally) is highly specialised (largely owing to the fact that during larval life the trabecular horns are involved in the support of the suprarostral cartilages) and markedly different from that of *Urodela*. A closer approach to the condition in the latter would result if in *Anura* the nasal septum were to disappear." (Op.cit.p.204 and p.206.) The space between the inner walls of the nasal sacs would thus correspond to the internasal space of the *Urodeles*. Born's [3] description and diagrams on the olfactory capsule of the larva of *Pelobates* likewise exhibit a marked resemblance to the *Brachycephalus* condition.

Viewed in the light of ontogeny the conditions obtaining in *Brachycephalus*, and to a less extent in *Elachistocleis*, would suggest, as already pointed out by Pentz ([31]), a neotenic condition. In the case of *Brachycephalus*, however, we should not disregard the possibility of specialisation in this particular respect. The condition might be explained by assuming that the lateral portions of the capsules were brought forward beyond the septum in order to form, with the aid of the large anterior premaxillary squames, a shovel-shaped structure at the tip of the snout as an adaptation to the fossorial mode of existence (Fig. 1). If this interpretation is tenable, it casts light on the peculiar position occupied by the medially directed superior prenasal cartilages. The assumption that the bifid condition of the nasal capsule is an expression of the retention of a larval condition caused by the exigency of a fossorial mode of life leads one to infer a similar adaptation for the larva.

(b) It has been pointed out that the fusion of the solum nasi with the lamina inferior and sometimes also with the crista intermedia is to be regarded as neotenic. This condition varies in its degree of extensiveness and *Brachycephalus* would represent an extreme case, unknown among other *Anura*, since here the fusion is so complete that no space for the accommodation of the nasal cavities normally situated in this region is allowed, either between the solum and the lamina inferior, or between the solum and the crista intermedia. Thus in *Brachycephalus* the recessus medialis lies directly posterior to the crista intermedia instead of ventral to it (Figs. 3c and 4a), and the recessus lateralis is situated at the niveau of the fenestra choanalis and posterior to the fused solum and lamina inferior, whereas in a form like *Elachistocleis* ([31]) in which the solum and the crista intermedia separate more anteriorly than do the solum and the lamina inferior, the recessus medialis extends further forward than the recessus lateralis. The position and the extent of development of the above mentioned nasal cavities in *Brachycephalus* are reminiscent of the relations obtaining in larval *Anura* ([48]) and ([41]). Granting that the architecture of the nasal capsule is dependent upon the development of the nasal cavities, the neotenic condition of the latter in *Brachycephalus* would be causal to the fusion of the solum with the lamina inferior and with the crista intermedia.

(c) The fenestra in the dorso-lateral part of the cartilaginous nasal roof, bounded laterally by the oblique cartilage and the planum terminale and medially by the tectum is regarded by Gaupp ([25]) as a primitive condition. The following is selected from his description of the development of the ethmoidal region: " Sehr interessant ist in dieser Hinsicht, dass nach Born (1877); (ich kann es für Bombinator bestätigen) bei Bombinator und Pelobates in Jüngeren Stadien das Planum terminale noch mit der Decke über dem hinteren Kapselabschnitt zusammenhängt und so wie bei den Urodelen eine Fenestra dorsalis von der Fenestra lateralis (infraconchalis) getrennt wird. Es ist dies als

primitiveres Verhalten aufzufassen." (p.733). Since, however, Born's specimens were not fully adult, and since this feature is not restricted to primitive forms such as *Pelobates* and *Bombina*, but also occurs in *Breviceps* and *Probreviceps* ([11]), *Spelaeophryne* ([18]), *Callulina* ([39]) and the highly specialised *Brachycephalus*, it is probably an instance of partial neoteny simulating primitiveness. An undoubtedly primitive condition in this respect is met with in the *Liopelmidæ* ([17]) in which the cartilago obliqua (and consequently also the fenestra dorsolateralis) is not differentiated from the tectum.

(d) The synchondrotic union of the cornu hyale with the pseudobasal process, occurring in *Brachycephalus*, *Atelopus* ([1]) and *Microbatrachella* ([15]) bears upon the much discussed problem of the homology of the Gauppian processus basalis palatoquadrati. It seems to be generally accepted that the basal process of the *Anura* is not homologous with that of the *Urodeles*, and accordingly the term " pseudobasal " is adopted in this paper.

Kruijtzer ([28]) in his work on the development of the chondrocranium of *Megalophrys montana* regards the pseudobasal process as a portion of the hyoid arch skeleton, and homologous with the pharyngohyal of *Neoceratodus*. De Beer ([6]) does not unconditionally accept the above interpretation, but is of opinion that further evidence is required for its confirmation. Developmental evidence is required to determine whether the hyo-pseudobasal union in *Brachycephalus*, *Atelopus* and *Microbatrachella* affords any support of Kruijtzer's view.

Pusey ([32]) holds that the pseudobasal process of the more typical Anurans is of basitrabecular and post-palatine origin, and belongs to the neurocranium and not to the quadrate. The process would thus be the isolated outer end of the basitrabecular process plus the post-palatine commissure behind it. Following the phases of Ranid development it is suggested that while the process develops from the base of the auditory capsule it is only secondarily fused to the quadrate and secondarily jointed onto the capsule. In line with the above argument and in view of the absence of the embryological evidence the possibility suggests itself that in *Brachycephalus*, *Atelopus* and *Microbatrachella* the hyoid cornu becomes primarily attached to that part of the auditory capsule which becomes incorporated into the pseudobasal process

The union between the hyoid cornu and the pseudobasal process might also be acquired during or after the process of separation of the latter from the auditory capsule. According to Pusey the process, in *Alytes*, is still fused to the auditory capsule by the post-palatine commissure and its outer posterior corner still gives an attachment to the hyoid cornu. If this interpretation proves to be valid, it is clear that the hyale is not always attached to the same region of the auditory capsule.

The above attempt to apply Pusey's views to the hyo-pseudobasal union appears to be opposed to the fact of a larval

hyo-quadratic union described by Gaupp ([23]). It should, however, be noted that, according to Gaupp, this union occurs only during early larval stages when the quadrate occupies a pre-orbital position, and that the synchondrotic union has already been lost when metamorphosis sets in. The possibility of a hyo-quadratic union prior to a hyo-pseudobasal one is, therefore, not excluded. Moreover, it also follows that if Pusey's view on the origin of the pseudobasal process holds, the hyo-quadratic union occurring in the adult *Brachycephalus*, *Atelopus* and *Microbatrachella* can no longer be regarded as a neotenic feature as interpreted by de Villiers ([15]).

(e) Since the otic process and the crista parotica are absent in *Brachycephalus*, there is no actual cartilaginous fusion of any of the processes of the quadrate with the neurocranium. With respect to the autostylic type of suspensorium, de Beer ([6]) points out that according to Huxley's definition of the term it can be applied to all Gnathostomes in which the hyo-mandibula plays no suspensorial function whether or not there be cartilaginous fusion between the jaw and the brain case. " To distinguish between these two conditions, however, de Beer and Moy-Thomas (1931) have introduced the modifications *autodiastylic* for the non-fused type possessed by ancestral fish, Gymnophiona and Amniota and *autosystylic* for the fused type represented by *Cyclostomes*, *Holocephali*, *Dipnoi*, *Urodela* and *Anura*." (de Beer, op.cit.p.422.) According to this terminology, *Brachycephalus* and *Acris* distinguish themselves in being decidedly autodiastylic among the otherwise autosystylic *Anura*. According to de Beer there can be no doubt that the autodiastylic type is the more primitive in phylogeny. Although it is not impossible for *Brachycephalus* to be primitive in this particular respect, we must always bear in mind that it is in other respects a highly specialised form. In this respect it is noteworthy that in the primitive Anuran *Ascaphus* ([16]) the crista parotica appears to be lightly pressed against the otic capsule instead of being in synchondrosis with it.

(f) The superficial bony plates occurring on the skull and along the back of the animal (one large and three small plates) are undoubtedly of the nature of secondary dermal ossification. That these plates are identical in the two regions becomes patent when those along the back are compared with those in the cranial region not underlain by other skeletal parts. Noble ([30]) refers to these structures in *Brachycephalus* as " a great calcareous plate on its back often ankylosed to the neural spines " (p.508), whereas previous authors such as Gadow ([22]) and Nieden ([29]) describe them as a broad dorsal shield of bone, fused with the processes of the second to the seventh vertebræ. We agree with the latter authors that these structures are not merely calcareous plates, but that they consist of dermal bone arising from the ossification of connective tissue fibres in the cutis. In both regions calcified fibres in the process of becoming bone of this type, and confluent with already ossified portions can

be clearly observed. In the same way as the bony shields on the back of the animal fuse with the vertebræ, the secondary dermal ossifications in the cranial region fuse with the normal dermal and cartilage bones, so that a bony continuity of the different components of the roof of the skull is effected. Morphologically these superficial bony plates fall in the category of ordinary membrane bone since they arise in the cutis. Histogenetically, however, they belong to the type known as fibre bone or "Faserknochen." According to Weidenreich ([49]) there is no contradiction in this interpretation since he considers all bone to be either "knorpelig präformierter Knochen" or "bindegewebig präformierter Knochen," the latter including both "Faserknochen" and ordinary dermal bone.

(g) The skull of *Brachycephalus* is extremely specialised. The following features can be regarded as some of the more outstanding specialisations: The possible absence of the quadratomaxillary, vomers, palatines and cartilaginous taeniæ; the absence of the middle ear and associated structures; the presence of a large operculum; more intensive and extensive ossification of the skull than that occurring in any other Anuran; the occurrence of secondary dermal ossification in the cranial region; the ossification of the quadrate; the presence of large anterior premaxillary squames. In this respect it is of interest to note that according to Noble ([30]) the primitive genus of each subfamily of the *Brachycephalidæ* is to a greater or less extent arciferal, and the specialised ones are firmisternal. Thus he mentions *Brachycephalus* and *Atelopus* as the two firmisternal and accordingly more specialised genera of the *Brachycephalinæ*. The two specimens of *Brachycephalus* examined are, however, both arciferofirmisternal (Fig. 9) so that according to Noble's criterion this genus is less specialised than *Atelopus*. The cranial anatomy of the two genera, however, does not substantiate this view.

(h) The numerous features of the cranial structure of *Brachycephalus* showing similarity to that of a likewise fossorial, but unrelated form, such as *Hemisus*, illustrate the importance of environment as causal to structure.

## SUMMARY.

1. The skull appears to be more intensively and extensively ossified than that of any other known Anuran.

2. Superficial bony plates of the nature of secondary dermal ossification occur along the back of the animal and on the skull, and fuse with underlying structures.

3. The anterior portions of the nasal capsules are separated from each other and reach well beyond the septum, so that each has its own inner wall.

4. The greater part of the olfactory capsule is ossified.

5. The alary is in synchondrotic union with the tectum nasi and its concave surface faces laterally instead of medially.

6. The superior prenasal cartilage is medially directed.

7. The anterior boundaries of the lamina inferior and of the lamina superior are fused with the crista subnasalis which is an antero-lateral extension of the solum.

8. The recessi of the cavum inferius retain their larval posterior position; the lamina inferior and the crista intermedia are completely fused with the solum nasi. Both these features are neotenic.

9. A fenestra in the cartilaginous nasal roof, reminiscent of the Urodelan fenestra dorsalis, is present.

10. The processus lingularis is continued posteriorly and passes over into the planum antorbitale, so that the fenestra choanalis is bounded laterally by a sagittal cartilage strip.

11. There is no eminentia olfactoria.

12. There is no trace in the adult of either the vomer or the palatine.

13. The septomaxillary is a small columnar bone and bears no relation to the nasolacrimal duct.

14. Both premaxillary and maxillary are edentulous.

15. The premaxillary is characterised by the presence of a large anterior horizontal squame.

16. The os en ceinture cannot be distinguished as such, since it is in bony continuity with the adjoining parts of the skull.

17. The olfactory nerves enter dorso-medially into the olfactory capsules.

18. Medially the frontoparietals are in bony continuity with each other and laterally with the ossified side walls of the cranial cavity.

19. The cranial floor is ossified in the orbital, otic and occipital regions.

20. The parasphenoid is fused to the cranial floor.

21. The taenia tecti transversalis and the taenia tecti medialis could not be located.

22. The otic capsule is intensively and extensively ossified.

23. Only one large perilymphatic foramen can be identified.

24. The middle ear and associated structures are absent.

25. An opercularised musculus levator scapulae superior is attached to a posterior extension of the large operculum.

26. The quadratomaxillary is apparently absent, so that the skull is gymnokrotraphic.

27. The otic process and the crista parotica are absent. The suspensorium is therefore autodiastylic as in *Gymnophiona*.

28. The pars quadrata is markedly invaded by the pterygoid

and paraquadrate, and the true quadrate bone probably exists together with these membrane ossifications.

29. The cornu hyale is in synchondrotic union with the pseudobasal process.

30. The anterior processes of the hyoid are long and well-developed although they are generally absent in the *Brachycephalinæ*.

31. The postero-lateral processes of the hyoid are absent in *Brachycephalus ephippium* as in all other species of the *Brachycephalinæ* that have been examined.

32. The elliptical cricoid cartilage is joined by a hyocricoid ligament to the thyroid process of the hyoid.

33. The pectoral girdle is arciferofirmisternal.

ACKNOWLEDGEMENTS.

My sincere thanks are due to Dr. C. A. du Toit and to Prof. C. G. S. de Villiers of the University of Stellenbosch for their guidance and constructive criticism. I am extremely grateful to Dr. du Toit for kindly placing the results of the work still in progress at my disposal.

BIBLIOGRAPHY.

(1) BADENHORST, E. C.: "Die Skedelmorfologie van die Neotropiese Anure *Atelopus moreirae* de Miranda-Ribeiro." (In progress.)

(2) BLUME, W.: "Studien am Anurenlarynx." *Morph.Jb.*, **65**: 307 (1930).

(3) BORN, G.: "Ueber die Nasenhöhlen und den Thränennasengang der Amphibien." *Morph.Jb.*, **2**: 577 (1876).

(4) BOULENGER, G. A.: Catalogue of the Batrachia Salientia s. Ecaudata in the Collection of the British Museum. London (1882).

(5) BOULENGER, G. A.: Les Batraciens. Doin et Fils, Paris (1910).

(6) DE BEER, G. R.: The development of the vertebrate skull. Univ. Press, Oxford (1937).

(7) DE MIRANDA-RIBEIRO, A.: "Notas para servirem ao estudo dos Gymno-batrachios (Anura) Brasileiros." Tomo primeiro. *Arch. Mus.Nac.*, Rio de Janeiro, **27**: 7 (1926).

(8) DE VILLIERS, C. G. S.: "The development of a species of Arthroleptella from Jonkershoek, Stellenbosch." *This Journal*, **26**: 481 (1929).

(9) DE VILLIERS, C. G. S.: "Some features of the cranial anatomy of Hemisus marmoratus." *Anat.Anz.*, **71**: 305 (1931a).

(10) DE VILLIERS, C. G. S.: "Further notes on the genus Cacosternum, including an account of the cranial anatomy of Cacosternum namaquense Werner." *This Journal*, **28**: 378 (1931b).

(11) DE VILLIERS, C. G. S.: "Uber den Schädelbau der Brevicipitidengattung Anhydrophryne (Hewitt)." *Anat.Anz.* **71**: 331 (1941c).

(12) DE VILLIERS, C. G. S.: "Uber den Schädelbau des Breviceps fuscus." *Anat.Anz.*, **72**: 164 (1931d).

(13) DE VILLIERS, C. G. S.: "The Cranial Characters of the Brevicipitid Genus Cacosternum (Boulenger)." *Quart.J.micr.Sci.*, **74**: 275 (1931e).

([14]) DE VILLIERS, C. G. S.: "Breviceps and Probreviceps: comparison of the cranial osteology of two closely related Anuran genera." *Anat.Anz.*, **75**: 257 (1933).

([15]) DE VILLIERS, C. G. S.: "Some points in the anatomy of Microbatrachella capensis (Hewitt), and their bearing upon the question of phylogenetic neoteny." *This Journal*, **31**: 406 (1934a).

([16]) DE VILLIERS, C. G. S.: "Studies of the Cranial Anatomy of Ascaphus truei Stejneger, the American 'Liopelmid.'" *Bull. Mus.comp.Zool.Harv.*, **77**: 1 (1934b).

([17]) DE VILLIERS, C. G. S.: "Some aspects of the Amphibian suspensorium, with special reference to the paraquadrate and quadratomaxillary." *Anat.Anz.*, **81**: 225 (1936).

([18]) DE VOS, C. M.: "Spelaeophryne and the bearing of its Cranial Anatomy on the monophyletic origin of the Ethiopian and Malagasy Microhylids." *Anat.Anz.*, **80**: 241 (1935).

([19]) DUMÉRIL, A. M. C. and BIBRON, G.: Erpétologie Générale ou Histoire Naturelle complète des Reptiles. Vol. 8. (The Amphibia here classified as "Reptiles"). Paris (1841).

([20]) DU TOIT, C. A.: "Some aspects of the Cranial Morphology of *Rana grayi* Smith." *Proc. Zool.Soc., Lond.*, p. 715 (1933).

([21]) DU TOIT, C. A.: "The Cranial Morphology of *Crinia georgiana* Tschudi (Cystignathidae, Amphibia)." *Proc.Zool.Soc.,Lond.*, p. 119 (1934).

([22]) GADOW, H.: Amphibia and Reptiles. *Camb.Nat.Hist.*, Vol. 8 (1901).

([23]) GAUPP, E.: "Beiträge zur Morphologie des Schädels. II: Das Hyo-Branchial-Skelet der Anuren und seine Umwandlung." *Morph.Arbeiten*, herausgeg. von G. Schwalbe, **2**: 399 (1892).

([24]) GAUPP, E.: A. Ecker und R. Wiedersheims Anatomie des Frosches. Auf Grund eigener Untersuchungen durchaus neu bearbeitet. Erste Abtheilung, 1896. Zweite Abtheilung, 1899. Dritte Abtheilung, 1904. Vieweg und Sohn, Braunschweig.

([25]) GAUPP, E.: Die Entwickelung des Kopfskelettes. *Hb.vergl. exp. Entwlehre Wirbt.*, herausgeg. von O. Hertwig, Vol. 3, pt. 2, p. 573 (1906).

([26]) GUNTHER, A.: Catalogue of the Batrachia Salientia in the Collection of the British Museum. London (1858).

([27]) HELLING, H.: "Das Geruchsorgan der Anuren, vergleichend-morphologisch betrachtet." *Z.Anat.Entwgesch.*, **108**: 587 (1938).

([28]) KRUIJTZER, E. M.: De ontwikkeling van het chondrocranium en enkele kopzenuwen van Megalophrys montana. H. van der Marck en Zonen, Roermond (1931).

([29]) NIEDEN, F.: "Anura II, Engystomatidae." *Das Tierreich*, Lief. 49 (1926).

([30]) NOBLE, G. K.: The biology of the Amphibia. McGraw Hill, New York and London (1931).

([31]) PENTZ, K.: "The Cranial Morphology of the Neotropical Microhylid (*Anura*) *Elachistocleis ovalis* (Schneider)." *This Journal*, **38**: 182 (1942).

([32]) PUSEY, H. K.: "Structural Changes in the Anuran Mandibular Arch during Metamorphosis, with reference to *Rana temporaria*." *Quart.J.Micr.Sci.*, **80**: 479 (1938).

([33]) RAMASWAMI, L. S.: "The cranial osteology of the South Indian *Engystomatidae* (Anura)." *Half-yearly J. Mysore Univ.*, **6**: 1 (1932).

([34]) RAMASWAMI, L. S.: "Contribution to our knowledge of the cranial morphology of some Ranid genera of frogs." Part II. *Proc.Ind. Acad.Sci*,, **2**: 1 (1935a).

([35]) RAMASWAMI, L. S.: "The Cranial Morphology of some examples of Pelobatidae (Anura)." *Anat.Anz.*, **81**: 65 (1935b).

([36]) RAMASWAMI, L. S.: "The Morphology of the Bufonid Head." *Proc. Zool.Soc.,Lond.*, p. 1157 (1936).

([37]) RAMASWAMI, L. S.: "Some aspects of the anatomy of Anura (Amphibia)—A review." *Proc.Ind.Acad.Sci.*, **10**: 49 (1939).

([38]) REINBACH, W.: "Untersuchungen über die Entwicklung des Kopfskeletts von *Calyptocephalus* Gayi." *Jena Z. Naturw.*, **72**: 211 (1939).

([39]) ROUX, G. H.: The cranial anatomy of *Callulina kreffti* Nieden. In press.

([40]) ROUX, G. H.: The cranial anatomy of *Microhyla carolinensis* (Holbrook). In press.

([41]) ROWEDDER, W.: "Die Entwicklung des Geruchorgans bei Alytes obstreticans und Bufo vulgaris." *Z.Anat.Entwgesch.*, **107**: 91 (1937).

([42]) SCHOONEES, D. A.: "Die skedelmorphologie van Bufo angusticeps (Smith)." *This Journal*, **27**: 456 (1930).

([43]) STADTMULLER, F.: "Kranium und Visceralskelett der Stegocephalen und Amphibien." *Hb.vergl.Anat.Wirbt.*. herausgeg. von Bolk, Göppert, Kallius und Lubosch **4**: 501 (1936).

([44]) TREWAVAS, E.: "The Hyoid and Larynx of the Anura." *Philos. Trans.Roy.Soc.,Lond.*, Ser. B, **222**: 401 (1933).

([45]) VAN EEDEN, J. A.: Die skedelmorfologie van *Elosia nasus* (Licht.). Tydskrif vir Wetenskap en Kuns, **3**: 75 (1943).

([46]) WAGNER, D. S.: "The structure of the inner ear in relation to the reduction of the middle ear in the Liopelmidae (Noble)." *Anat. Anz.*, **79**: 20 (1934a).

([47]) WAGNER, D. S.: "On the cranial characters of Liopelma hochstetteri." *Anat.Anz.*, **79**: 65 (1934b).

([48]) WATANABE, M.: "Über die Entwicklung des Geruchsorgans von Rhacophorus schlegelii." *Z.Anat.Entwgesch.*, **105**: 35 (1936).

([49]) WEIDENREICH, F.: Das Knochengewebe. *Hb.Mikr.Anat.Menschen*, **2**: 391 (1928).

The quotations from work in progress have been made by kind permission of the authors concerned.

## FIGURES AND ABBREVIATIONS.

Fig. 1: Graphical reconstruction of the nasal capsule of *Brachycephalus*. X 37½. Dorsal view. The left half of the bony nasal roof is removed and the asperites on the surface of the roof are not indicated. Cartilaginous parts are stippled.

Fig. 2: Consecutive transverse sections through the region of the external narial aperture.

Fig. 3: Consecutive transverse sections through the nasal capsule in the region of the convergence of the anteriorly separated parts.

Fig. 4: Consecutive transverse sections through the nasal capsule in the region of the fenestra choanalis.

Fig. 5: Consecutive transverse sections through the anterior region of the auditory capsule.

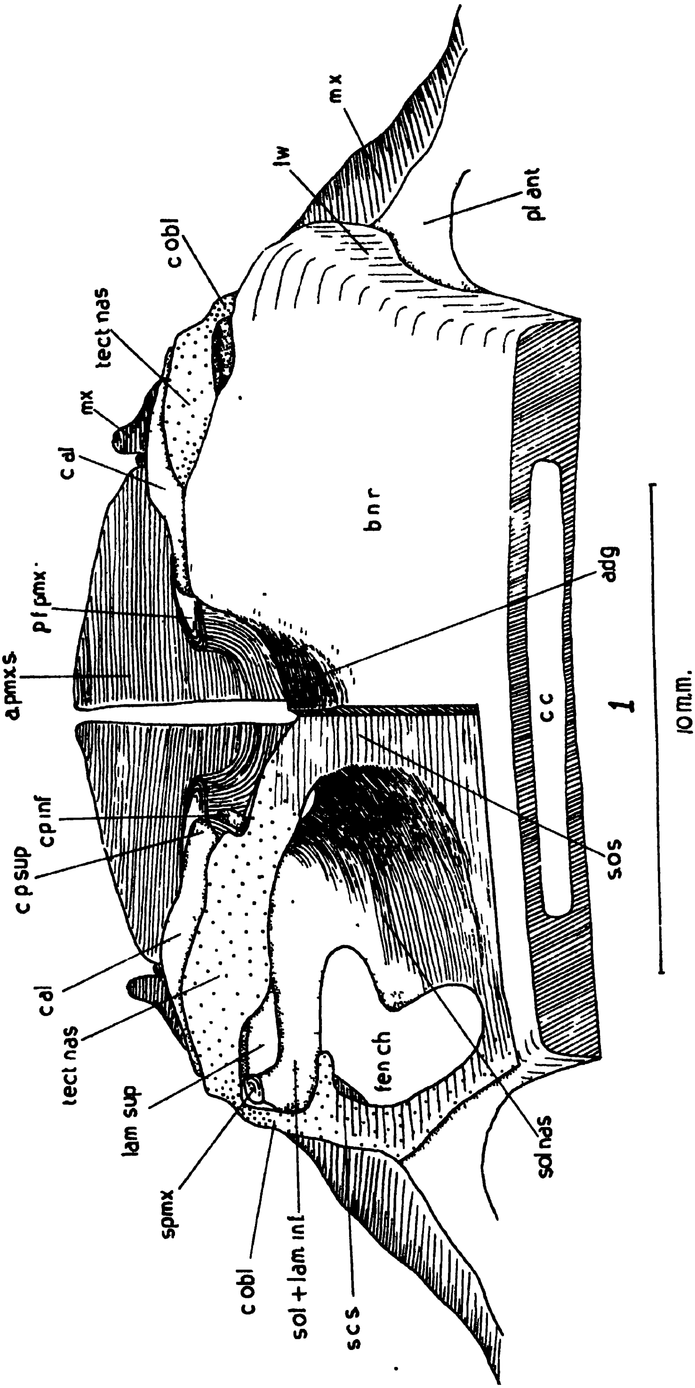
Fig. 6: Consecutive transverse sections through the auditory capsule in the region of the fenestra ovalis.

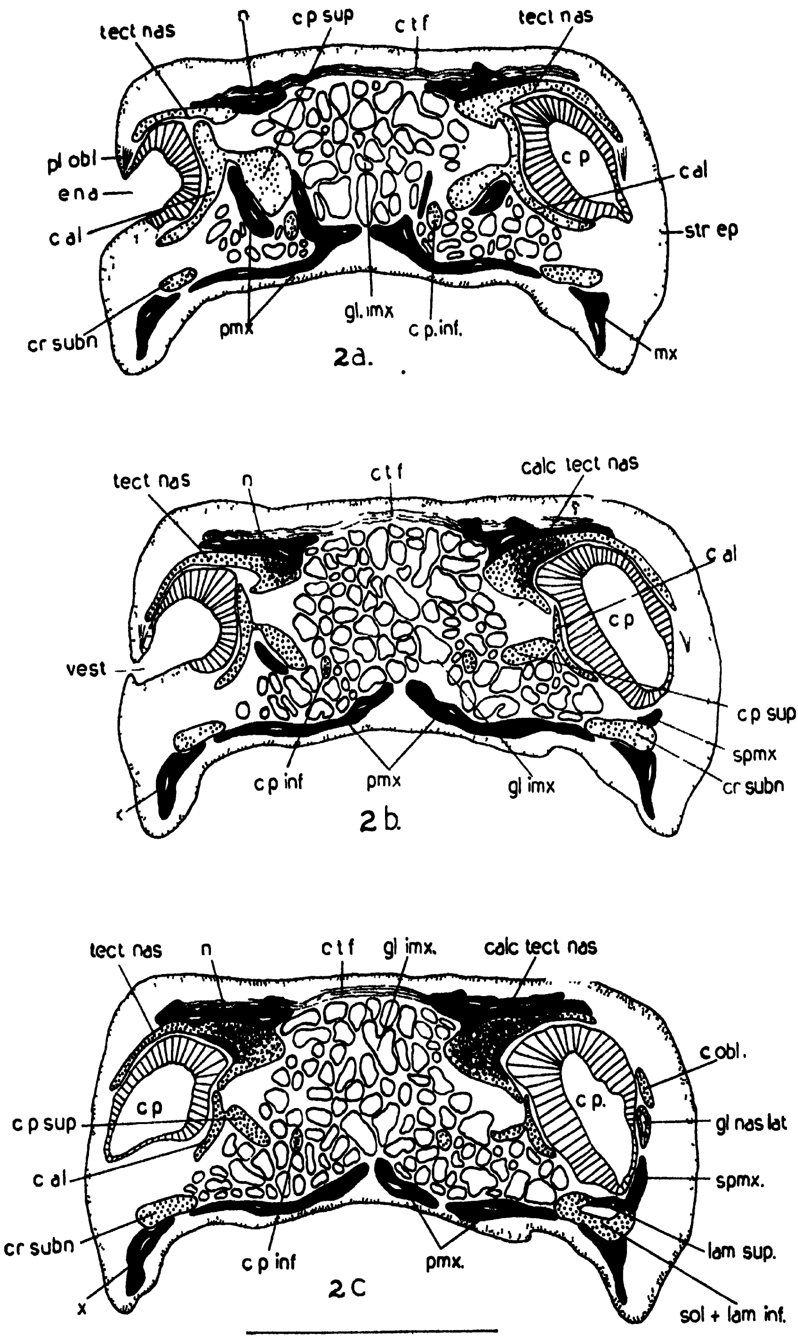
Fig. 7: Transverse section through the posterior region of the auditory capsule.

Fig. 8: Graphical reconstruction of the hyoid apparatus of *Brachycephalus*. X 25. Dorsal view.

Fig. 9: Transverse section through the larynx.

a.d.g., anterior dorsal groove; a. pmx.s., anterior premaxillary squame; ar., arytaenoids; b.n.r., bony nasal roof; b.r., bony root; c.al., cartilago alaris; calc. tect. nas., calcified tectum nasi; cav. cr., cranial cavity; cav. med., cavum medium; c.c., cranial cavity; c. obl., cartilago obliqua; col. ep., columnar epithelium of the buccal cavity; corac., coracoids; cor. hy., cornu hyale; corp. hy., corpus hyoideum; c.p., cavum principale; c.p. inf., cartilago praenasalis inferior; c.p., sup., cartilago praenasalis superior; cr. int., crista intermedia; cr. int. & sol., fused crista intermedia and solum nasi; cr. subn., crista subnasalis; cric., cricoid; c.t.f., connective tissue fibres; d. nasol., ductus nasolacrimalis; d. pulv., dorsal pulvinaria; e.c.c., extracapsular cavity; e.n.a., external narial aperture; f.f.o., fossa fenestrae ovalis; fen. ch., fenestra choanalis; fen. nasob., fenestra nasobasalis; fen. ov., fenestra ovalis; for. ac. ant., foramen acusticum anterior; for proot., foramen prooticum; gl. imx., glandula intermaxillaris; gl. nas. lat., glandula nasalis lateralis; gl. nas. med., glandula nasalis medialis; gon., goniale; hyocr. lig., hyocricoid ligament; in. e., cavity ot the inner ear; inf., infundibulum; l.m. fen. ov., lower margin of the fenestra ovalis; l.w., lateral wing of the nasal roof; lam. inf. & pl. term., fused lateral margin of the lamina inferior and the planum terminale; lam. sup., lamina superior; M.c., Meckel's cartilage; man., manubrium of the hyoid; mx., maxillary; n., nasal; o.d.o., overhanging wing of dermal ossification; op., operculum; p.f. pmx., facial part of the premaxillary; p.q. pq., pars quadrata palatoquadrati; paraq., paraquadrate: pl. ant., planum antorbitale; pl. obl., plica obliqua; pmx., premaxillary; proc. ant., processûs anteriores; proc. pseud., processus pseudobasalis; proc. pter., processus pterygoideus; proc. thyr., processûs thyreoidei; pter., pterygoid; r.m.n., ramus medialis narium; rec. lat., recessus lateralis; rec. med., recessus medialis; s.c.s., sagittal cartilage strip; s.o.s., horizontal section through the left half of the ossified septum; sept., septum nasi; sol. & lam. inf., fused solum and lamina inferior; sol nas., solum nasi; spmx., septomaxillary; str. ep., stratified epithelium; syn. con., syndesmotic connection between the auditory capsule and the upper jaw; tect. nas., tectum nasi; v. pulv., ventral pulvinaria; vest., vestibulum.

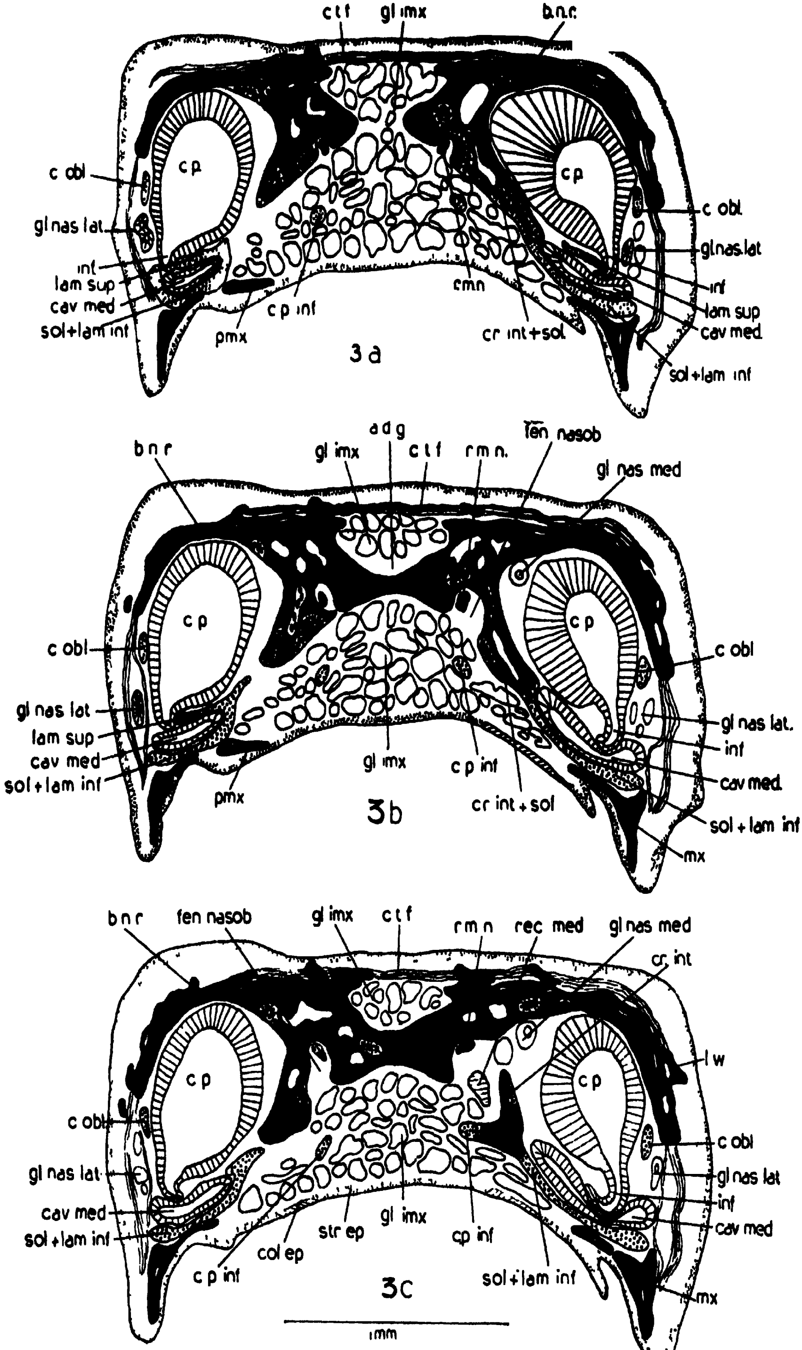

mx
lw
pl ant
c obl
tect nas
mx
c al
b n r
pl pmx
a pmx s
adg
c c
1
10 m.m.
sos
cp inf
c p sup
c al
tect nas
lam sup
fen ch
sol nas
spmx
c obl
sol + lam inf
s c s

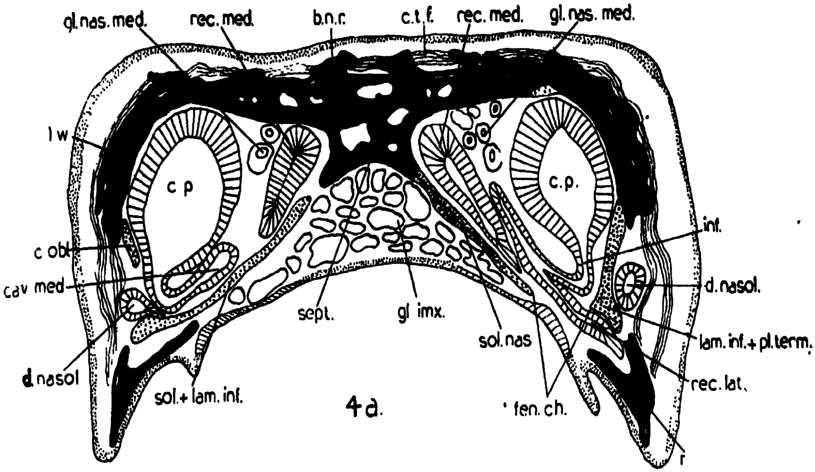

tect nas
n
c p sup
c t f
tect nas
pl obl
e n a
c al
c p
c al
str ep
cr subn
pmx
gl. imx
c p. inf.
mx
tect nas
n
c t f
calc tect nas
c al
c p
vest
c p sup
spmx
cr subn
c p inf
pmx
gl imx
x
tect nas
n
c t f
gl imx.
calc tect nas
c obl.
c p
c p.
c p sup
gl nas lat
c al
spmx.
cr subn
lam sup.
c p inf
pmx.
x
sol + lam inf.

2a.

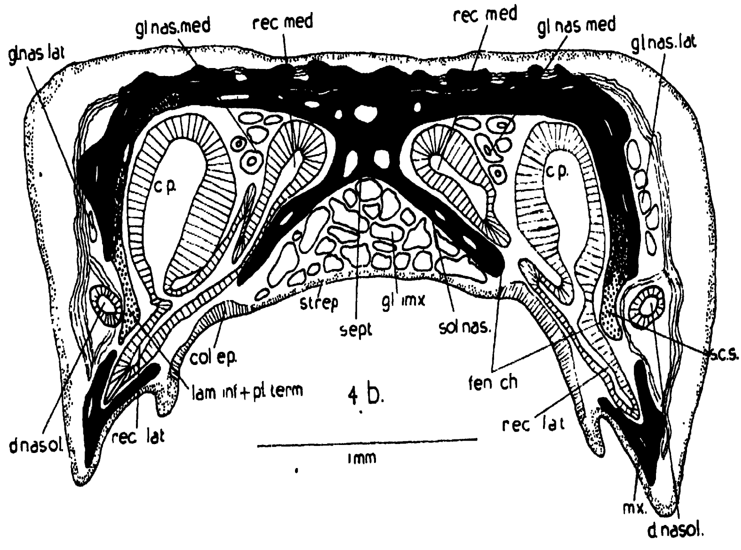
2 b.

2 C

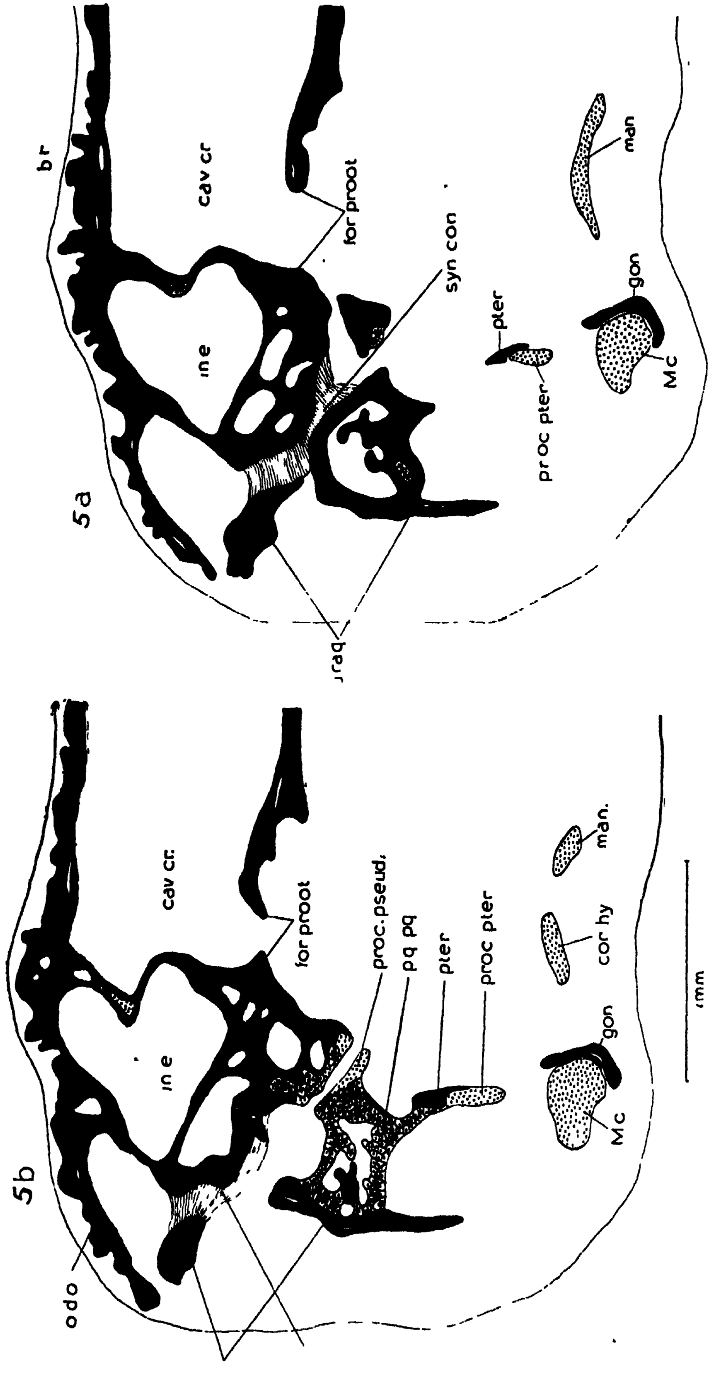

c t f
gl imx
b.n.r.
c obl
gl nas lat
inf
lam sup
cav med
sol+lam inf
c p
pmx
c p inf
cmn
cr int+sol
3 a
a d g
b n r
r m n.
fen nasob
gl nas med
gl nas lat.
cav med
sol + lam inf
mx
3b
rec med
cr int
l w
str ep
col ep
3c
1mm

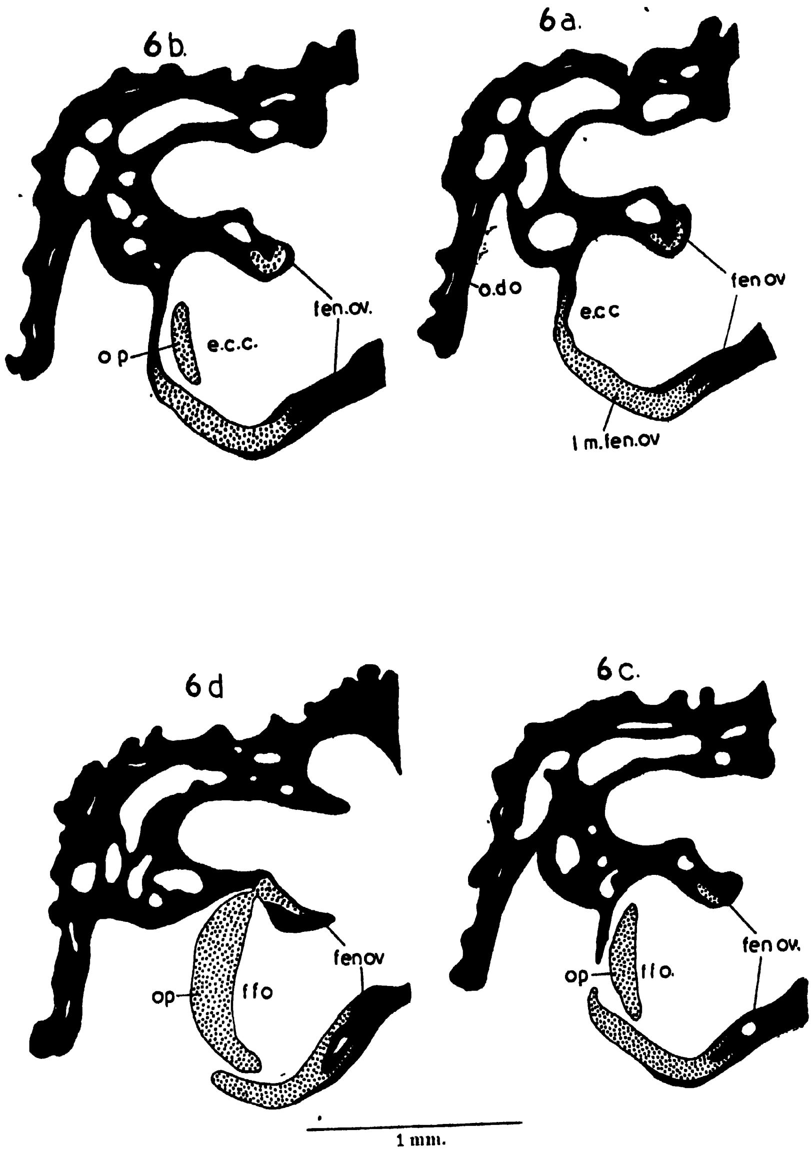

gl.nas.med.
rec.med.
b.n.r.
c.t.f.
rec.med.
gl.nas.med.
l w
c p
c.p.
inf.
c obl
cav med
d.nasol.
sept.
gl imx.
lam.inf.+pl.term.
sol.nas
d.nasol
rec.lat.
sol.+lam.inf.
fen.ch.
r

4a.

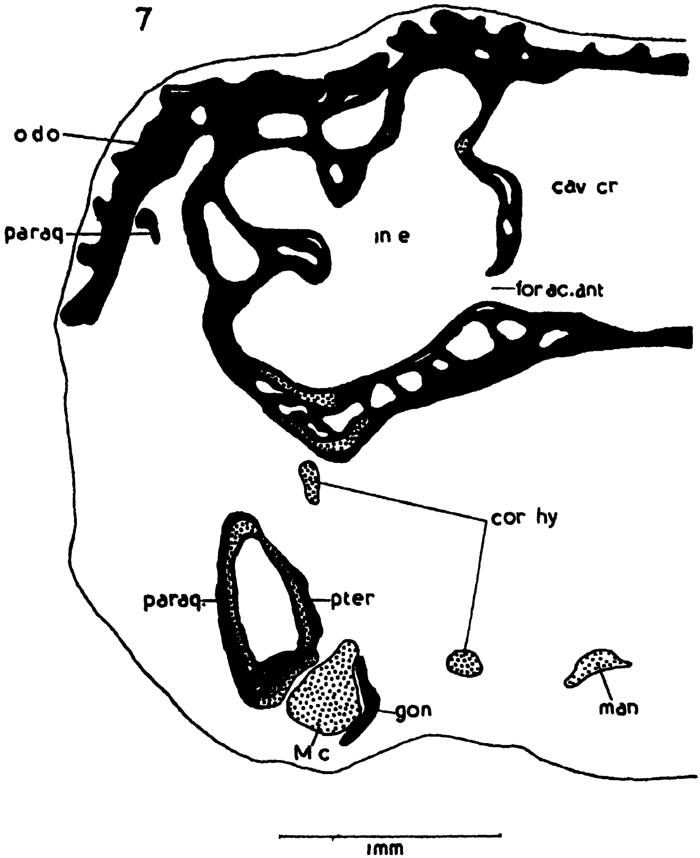

gl nas.med
rec med
rec med
gl nas med
gl nas lat
gl nas.lat
c p
c p.
strep
gl imx
sept
sol nas.
s.c.s.
col ep.
lam inf+pl term
fen ch
rec lat
d nasol
rec lat
1mm
mx.
d nasol.

4 b.

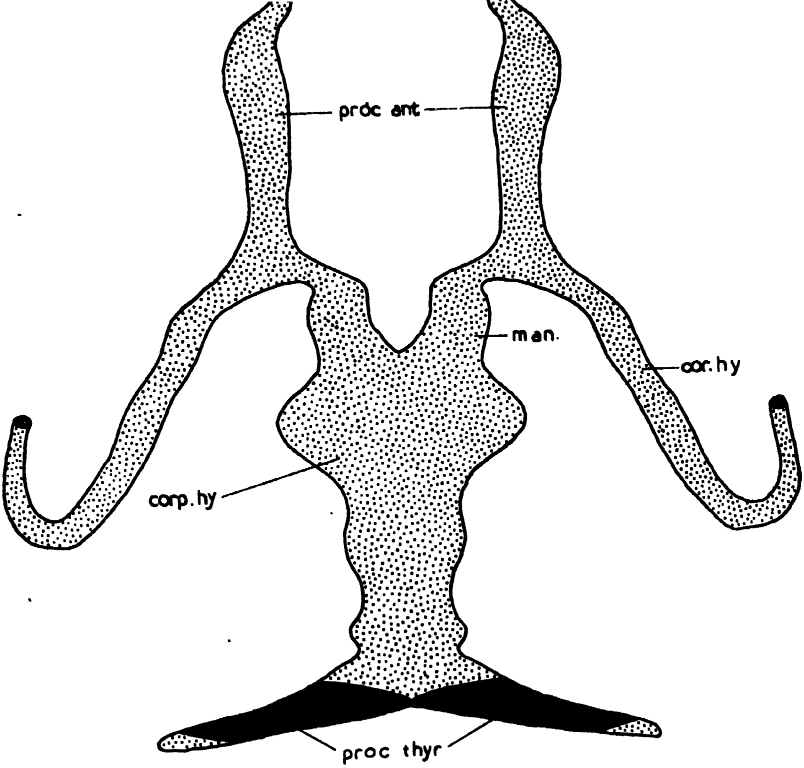

5a
br
cav cr
for proot
syn con
ine
pter
proc pter
man
gon
Mc
5b
odo
cav cr.
for proot
ine
proc. pseud.
pq pq
pter
proc pter
man.
cor hy
gon
Mc
1mm


6b.
6a.
o.do
fen ov
fen.ov.
e.c.c.
e.c c
o p
l m.fen.ov
6d
6c.
fenov
fen ov.
op
ffo
op
f f o.
1 mm.

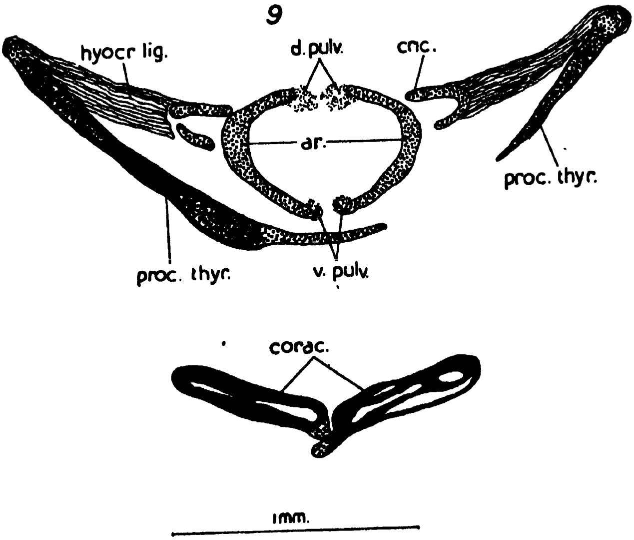
7



8


proc ant
man.
cor. hy
corp. hy
proc thyr

9


hyocr lig.
d. pulv.
cric.
ar.
proc. thyr.
proc. thyr.
v. pulv.
corac.
1mm.

South African Journal of Science, *Vol. XL, pp. 196-212, November, 1943.*

# ON THE CRANIAL MORPHOLOGY OF THE WEST AFRICAN ANURAN *Petropedetes johnstoni* (Boulenger).

BY

C. A. du Toit,

*Zoological Institute, University of Stellenbosch.*

*With 5 Text-figures.*

*Read 29th June, 1943.*

## Introduction.

*Petropedetes cameronensis*, the type species of this genus, was first described and figured in 1874, by Reichenow, who discovered it some years earlier in the Cameroons. He, however, erroneously regarded it as one of the *Hylidæ*. Two more species from the same region were described by Boulenger (1887) as *Cornufer johnstoni* and by Bocage (1895) [quoted from Boulenger, 1900] as *Tympanoceros newtonii*, respectively. Boulenger (1900), however, rectified these mistakes, referring both species to the genus *Petropedetes* and also changing the specific name *newtonii* to *newtoni*. In 1905, Boulenger described two more species: *P.natator* from Sierra Leone and *P.palmipes* from South Cameroon. The next important references to these frogs are contained in H. W. Parker's paper on the zoogeography and systematics of the Amphibians of the Mamfe Division, Cameroons, and in Sanderson's account of the ecology of the frogs in this region, both published in 1936. Parker, having at his disposal the large Sanderson collection amply provided with reliable field notes, could show that *Petropedetes johnstoni*, apart from manifesting certain growth changes, is subject to a large amount of seasonal and sexual variation. He divides the species into different age and sex groups, giving detailed descriptions of each, in this way clearing up the previous taxonomic confusion. As far as the skull is concerned, all these descriptions refer only to external features, and it is not surprising that all these investigators have overlooked the important fact that *Petropedetes johnstoni* possesses a divided vomer, as my investigations have shown.

Noble (1931) created the *Petropedetinæ*, as a sub-family of the *Ranidæ*, to include the two genera *Petropedetes* and *Arthroleptides*. In a previous paper (du Toit, 1938) I gave an account of the cranial anatomy of the latter, and the investigation of the cranial morphology of *Petropedetes* was undertaken not only to test the validity of Noble's classification, but also to gain

more comparative data for the proper evaluation of the Anuran skull. The lower jaw of *Arthroleptides* shows a peculiarity which might prove to be of great importance; in the case of *Petropedetes* the chief interest seems to centre round the vomer. The cranial nerves, bloodvessels and muscles, the breast-shoulder apparatus, the vertebral column and the thigh muscles of the *Petropedetinæ* and other allegedly related species are being investigated by myself and other research workers in this Institute, and not until these results are available and correlated, will it be possible to arrive at some conclusion regarding the proper taxonomic position and the phylogenetic significance of the *Petropedetinæ*.

## MATERIAL AND TECHNIQUE.

My sincere thanks are due to Mr. F. R. Parrington, Director of the University Museum of Zoology, Cambridge, who kindly provided me with four specimens of *Petropedetes johnstoni* (Nos. 166H, 659H, 581H and 527H: Sanderson Collection of Amphibia from the Cameroons, 1932-33). The skull of the largest specimen (No. 527H), a second year breeding female measuring 58 mm. from vent to tip of snout, was macerated and studied macroscopically; the skulls of the other specimens were prepared in the usual way for microscopic investigation.

The adjective "Ranid," as used in this paper, refers to Gaupp's descriptions of *Rana fusca*, *R.esculenta* and *R arvalis* and not to the *Ranidæ* in general.

## THE OLFACTORY CAPSULE.

The general appearance of the olfactory capsule of the juvenile is typically Ranid, but with age it becomes dorsoventrally flattened; concomitantly there can be observed a marked relative decrease in the size of the cartilaginous olfactory capsule and a corresponding increase in the size of the dermal bones. The alary and both the prenasal cartilages are present, the latter having the usual relationships to the premaxillary. In the juvenile the septum and the fenestra nasobasalis are typically Ranid, but in the adult the anterior part of the septum is much reduced with the result that the fenestra has, relative to the rest of the capsule, been shifted backwards (Fig. 1).

In all the forms hitherto investigated, the crista subnasalis is a medially flexed cartilaginous ridge attached to the ventral side of the lateral edge of the solum nasi, but in *Petropedetes* it is situated on the ventral side of the solum at about a third the distance from its edge to the septum (Fig. 1). This peculiar position of the crista may be due to the rather large palatal process of the maxillary (Fig. 1). The anterior part of the crista subnasalis lies dorsal to the maxillary and to the premaxillary, but further back it separates the palatal process of the maxillary from the lateral palatal squame of the premaxillary. Whether the crista merely lies dorsal to these processes or separates them from each other appears to be of

little importance. The cristæ subnasales serve as two struts supporting the palatal processes of the maxillary and of the premaxillary away from the solum nasi, thereby increasing the subnasal space for the accommodation of the intermaxillary gland.

In both the juvenile and the adult the crista intermedia is normally developed. In the juvenile, the lamina inferior, in addition to its usual attachments, is anteriorly also fused to the solum nasi for some distance so that the recessus lateralis of the cavum inferius is the last of the nasal cavities to appear in section. In the adult the configuration of the nasal capsule in this region and the order of appearance of the nasal cavities conform to the Ranid type, the only deviation being the absence of the side wall of the capsule in both specimens. It would appear, therefore, that with growth the recessus lateralis gradually extends forwards to the position it occupies in the adult. The anterior part of the lamina inferior and the solum had, therefore, to be separated, the process entailing a certain amount of resorption of cartilage, before the adult condition could be attained to.

The rest of the olfactory capsule conforms to the Ranid type.

### THE NASAL CAVITIES.

Mention has been made of the difference in the relative positions of the nasal cavities in the juvenile and in the adult. Except for the fact that the recessus sacciformis is represented by a very small infundibular recess, the identity of which is chiefly established by the insertion into its wall of a number of fibres of the musculus lateralis narium, the general configuration of the nasal cavities is typically Ranid.

Only the anterior "Wulst," supporting the posterior part of the lateral wall of the vestibulum, is present. The anterior part of the plica obliqua, which is suspended from the tectum, is short, but posteriorly it increases in length and fuses with the lateral vestibular wall immediately ventral to the " Wulst;" from this point backwards the vestibulum is continued as a short groove.

Helling (1938) introduces a new terminology for the vestibular and infundibular regions of the nasal cavities. In a comparative analysis of the skulls of certain Microranids, which I hope to complete in the near future, I shall deal at some length with the anatomical and physiological basis of Helling's terminology; suffice it to state here, that I cannot accept his interpretation. In the accounts of the cranial morphology of *Heleophryne regis* (1930) and of *Rana grayi* (1938), I described and figured a small ventro-median pouch in the anterior part of the floor of the cavum principale and called it the ventro-median recess. Helling (1938) describes an obviously homologous structure in several other species and proposes the name recessus olfactorius for it. This appellation connotes an olfactory function, but since the whole of the cavum principale is endowed with this function,

the term apparently suggests a special perceptive sense for this region, a contention which is not proven. It would, therefore, be wiser to retain the non-committal term ventro-median recess (recessus ventromedianus cavi principalis). The recess is bounded laterally by the plica terminalis, and medially it is separated from the rest of the olfactory epithelium by a narrow strip of indifferent epithelial cells, which appears as a fold in those species in which the structure is well-developed. On the median side of this recess is situated a gland of varying size; its short duct pierces the zone of indifferent epithelium. This gland was first recognised as a separate entity by Foske (1934), who called it the glandula oralis interna, obviously not a well chosen term. *Petropedetes* possesses a small recessus ventromedianus with which a glandula oralis interna consisting of only a few tubules is associated.

The only other point worthy of being mentioned is the fact that a few fibres of the musculus lateralis narium originate from the dorsally flexed lateral edge of the lamina inferior as in *Rana grayi* (du Toit, 1933).

## Glands of the Olfactory Region.

The well developed intermaxillary gland is entirely extracapsular, its tubules occupying the pre- and subnasal spaces. On either side its lateral portion lying between the floor of the recessus lateralis and the palatal process of the maxillary extends further back than its median portion, which does not reach beyond the posterior ends of the palatal squames of the premaxillary. The ducts converge towards the middle line, extend backwards and then open irregularly into the buccal cavity some distance in front of the choanæ. *Petropedetes* would, therefore, belong to Muller's "2nd type."

In the choanal region the "Rachendruse" consists of two sets of tubules: those of the lateral division, which are embedded in the connective tissue forming the dorsal part of the plica isthmi, run the length of the choana, but those of the median division do not reach so far forward. It is not quite correct to say that the tubules fringe the median as well as the lateral border of the choana, as Gaupp maintained, since the lower outer border of the choana is formed by the plica palatina and not by the plica isthmi. Near the posterior end of the choana the lateral division acquires an opening (Fig. 2a), and only a few sections further back the median one also opens into the buccal cavity near the lateral edge of the anterior vomer (Fig. 2b). In the same transverse plane, at the dorsal extremity of the plica isthmi, can be seen the anterior part of a large oblong opening stretching from before backwards and inwards (Fig. 2b). This is the buccal opening of a reservoir situated in the posterior choanal wall and receiving ducts from both the lateral and the median divisions of the gland (Fig. 2c). Behind this region the two divisions of the gland merge into each other, the tubules extending backwards, but not reaching the posterior limits of the cavum

principale. The significance of the separate median and lateral openings of the gland is discussed in a previous paper (du Toit, 1938) to which the reader is referred.

The glandula nasalis medialis is normally developed; its duct opens from the lateral side into the short blind posterior extension of the recessus medialis.

The glandula nasalis lateralis which is situated entirely median to the fibres of the musculus lateralis narium does not differ from the usual type.

As described in a previous section, *Petropedetres* possesses a small glandula oralis interna opening into the recessus ventro-medianus.

### Membrane Bones of the Olfactory Region.

The premaxillary does not deviate from the usual type, but the maxillary is characterised by the possession of a large palatal process (Fig. 1). The dentition of both bones, however, is of the acrodont type.

In the juvenile the nasals are two small bones widely separated from each other. Each stretches from a point immediately behind the attachment of the cartilago obliqua to the tectum, to the posterior edge of the planum antorbitale. Near the middle of its length each nasal acquires a rod-like shape and a large marrow cavity (Fig. 2). The frontal process of the maxillary does not establish contact with the nasal. Subsequent growth of the bone is evidenced by the development of a thin medially directed wing-like expansion of its anterior two-thirds, so that in the adult its medial border almost coincides with the line of junction between the tectum and the septum.

The septomaxillary shows the triradiate shape characteristic of the *Anura*. The anterior process has two short prongs shown in Fig. 1. These fuse with each other thus clasping the lateral edge of the lamina superior and forming part of the roof of the cavum medium. Immediately posterior to the fusion of the two prongs the bone again divides into a median and a lateral process. The former is a splint-like bone tipping the lateral edge of the lamina superior, whereas the latter is a laterally compressed blade lying on the median side of the glandula nasalis lateralis. The part of the infundibulum which communicates with the cavum medium lies between these two processes. The lateral process gradually shifts from a vertical into a horizontal position and in the region where the nasolacrimal duct communicates with the cavum medium it gives off a short antero-ventrally directed process, the anterior tip of which appears between the floor of the cavum medium and the dorsal surface of the lamina inferior. This process thus serves as a skeletal protection for the region where the nasolacrimal duct enters the cavum medium. The main lateral process is continued backwards for some distance as a membrane bone on the dorsal surface of the lamina inferior, disappearing from section immediately anterior to the posterior limits of the median process and of the lamina superior.

*Petropedetes* has a divided vomer. Upon the establishment of the processus lingularis the anterior division of the vomer appears as a thin splint-like bone applied to the lateral edge of the solum. It gradually increases in size becoming a spatulate bone slightly underlying the lateral edge of the solum and forming a ventral support for part of the cavum principale. Its lateral edge is produced into a sharp process bounding the choana anteriorly. Proceeding backwards along the median border of the choana, it decreases in size, regaining its prechoanal dimensions and, sweeping outwards in a gentle curve, it disappears a short distance behind the choana. In the juvenile neither the posterior division of the vomer nor the palatine reaches as far forwards as the posterior end of the anterior division of the vomer; in the adult on the other hand, both these bones appear medially to the anterior division of the vomer in front of the posterior edge of the choana. The posterior division of the vomer first appears ventrally to the anterior end of the palatine; it then fuses with the latter for a short distance and regains its identity in the region of the vomerine teeth. The latter numbering about eight on either side are arranged in a transverse row across the whole width of the bone. The two palatines almost meet each other medially between the two posterior divisions of the vomers.

Until 1934, when I demonstrated the presence of a divided vomer in the Australian Cystignathid *Crinia georgiana*, this feature was considered to be confined to certain Malagasy and Indo-Malayan *Microhylidæ* (Noble and Parker, 1926 and Parker, 1931). Parker (op.cit.) is of opinion that, as a result of parallel evolution, a divided vomer has arisen independently in these two groups of *Microhylidæ* inhabiting two different zoogeographical regions. In the present state of our knowledge it is not deemed advisable to make any suggestion regarding the possible phylogenetic significance of the conditions obtaining in *Petropedetes*.

### The Os en Ceinture.

Since the homology of the cartilage bone, which arises as paired perichondral ossifications of the preoptic roots of the orbital cartilages (therefore, representing the orbitosphenoids, according to some authors), but which also extends to a varying degree into the olfactory capsules, is not established, it is best to designate it by the non-committal term os en ceinture, as originally suggested by Cuvier. In the juvenile the first traces of the bone appear immediately posterior to the orbito-nasal foramina as perichondral bony lamellæ on both internal and external surfaces of the ventro-lateral aspects of the brain-case. Proceeding backwards these ossifications gradually extend upwards until the entire side walls of the brain-case, with the exception of the laterally directed cartilaginous ledge dorsal to each orbitonasal foramen, are perichondrally ossified. In the juvenile, therefore, the bone is paired, since the floor of the brain-case, underlain by the tip of the parasphenoid, remains cartilaginous.

In the adult the os en ceinture has much the same shape as in the European *Rana*, but relative to the rest of the skull, it occupies a more posterior position. It extends from behind the posterior divisions of the vomers to about the middle of the orbit. In section the first signs of the bone appear, at the level of the posterior surfaces of the plana antorbitalia, as perichondral ossifications of the internal surfaces of the tectum These ossifications gradually extend downwards along each side of the septum. The orbitonasal foramen is completely surrounded by perichondral bone, even the ledge which lies dorsal to it and usually remains cartilaginous, is perichondrally ossified. Proceeding backwards the ossification spreads so that the hindmost portions of the cava principalia are encased in bone and the entire anterior part of the brain-case is both perichondrally and enchondrally ossified. A short distance further back the anterior limits of the frontal fenestra are encountered and in this region the bone is restricted to the sides and floor of the brain-case.

### The Orbital, Otic and Occipital Regions.

The brain-case does not deviate to any significant extent from that of the European *Rana*. In the *Anura* the roof of the brain-case is subject to a fair amount of variation (vide also Stadtmüller, 1936), but in *Petropedetes* the conditions are typically Ranid; both the taenia tecti medialis and the taenia tecti transversalis being present as in *Bufo* (Schoonees, 1930), *Rana grayi* (du Toit, 1933) and *Arthroleptides* (du Toit, 1938). With the exception of a small amount of connective tissue surrounding the optic nerve and the arteria carotis cerebralis respectively, the wall of the neurocranium between the os en ceinture and the prootic is completely cartilaginous. As in *Arthroleptides* the arteria carotis cerebralis has its own foramen, situated ventrally to that of the IIIrd nerve. This condition is apparently not rare, for besides occurring in some specimens of the European species of *Rana*, it is also found in *Crinia*.

Owing to the well-developed laterally projecting cristæ paroticæ the otic region is wider, giving the whole skull a more triangular appearance than in the European *Rana*. Allowing for the different proportions of the capsule, the prootic and the exoccipital do not deviate from the Ranid type, and they are not fused with each other as in *Arthroleptides*. The ventral border of the foramen magnum is hardly notched, but dorsally there exists a large V-shaped bay between the two exoccipitals. The two acoustic foramina are situated close to each other, the anterior border of the posterior one being formed by the prootico-exoccipital cartilage. The two perilymphatic foramina are separated from each other by a thin osseous bridge; the superior foramen opens directly into the cranial cavity as does also the anterior part of the large inferior one. The posterior portion of the latter opens ventrally into the jugular foramen. In other respects the otic region is typically Ranid.

The narrow anterior end of each frontoparietal is applied to the cartilaginous ledge on the dorsal side of the orbitonasal foramen. Proceeding backwards the bone broadens out and at the level of the posterior border of the dorsal part of the os en ceinture it almost meets its partner on the opposite side. In the region of the taenia tecti transversalis the median border of each bone is widely indented. The lateral border of each frontoparietal is produced ventrally, thus covering the dorsal part of the cartilaginous lateral wall of the brain-case. The dorso-lateral portion of each bone, which is provided with a large marrow cavity, has the shape of a thick ridge. Its posterior portion does not overlap either the prootic or the exoccipital.

The parasphenoid conforms to the Ranid type.

## The Sound Conducting Apparatus.

The sound conducting apparatus is typically Ranid in structure. The pars externa plectri is not enlarged to form an extraplectral. *Petropedetes* is apparently one of those forms in which the processus ascendens partis externæ plectri is in the process of being transformed from a cartilaginous rod into a ligament. In both the juvenile and in the adult a few cartilage cells are retained, especially at the outer and inner ends of the process, but in the adult the whole process is more strongly ligamentous than in the juvenile (Fig. 4d). Similar conditions obtain in *Arthroleptides* and in a few other species.

The dorsal posterior part of the ring-shaped annulus tympanicus is confluent with the crista parotica.

The development of secondary sexual characteristics, culminating in sexual dimorphism, is a common phenomenon among the *Anura*. These characteristics may be either permanent, being in evidence throughout the adult life of the animal; or, they may be seasonal, attaining their maximal development only during the period when the animal is in full nuptial dress, and when reproduction can take place. Failure to recognise an anatomical peculiarity as a secondary sexual characteristic, or to distinguish clearly between permanent and seasonal secondary sexual characterisitcs, often leads to much confusion as becomes evident from a perusal of the literature on *Petropedetes*. Parker (op.cit.) and Sanderson (op.cit.), having had at their disposal a large number of specimens acquired during a year's continual collecting, could distinguish clearly between these two types of secondary sexual characteristics. According to Parker (op.cit.) the tympanum of the mature male is much larger than that of the mature female, this being one of the permanent secondary sexual features. As far as could be ascertained, *Petropedetes* is unique in possessing a seasonal secondary sexual characteristic in the form of a so-called tympanic papilla. The latter, which Noble (1931) mistook for the pars externa plectri " thrust through the drum," is in reality a thickened portion of the

outer dermal part of the tympanic membrane. Other authors have recognised its true nature, but thought that it was situated opposite the insertion of the pars externa plectri into the tympanum. An inspection of Fig. 5 shows, however, that the papilla is attached to the tympanum dorsal to the insertion in question. The papilla consists of both the epidermal and cutis components of the skin, whose deep, compact layer consisting chiefly of collagenous fibres is continued only into the base of the papilla; its bulk is formed by the loose upper part of the cutis covered by the epidermis. Glands, presumably all of the mucous variety, and sparsely scattered throughout the tympanic membrane, are more concentrated in the papilla. The subepidermal pigment layer too, is better developed here than elsewhere. The superficial cornified layer of the epidermis is thicker than that over the rest of the tympanum and is produced into tiny wart-like asperities (Fig. 5).

## The Palatoquadrate and the Suspensorial Region.

The two outstanding peculiarities of the suspensorial region of the palatoquadrate are the well-developed, laterally projecting crista parotica and the otic process, which, from the region of its confluence with the crista parotica, is directed forwards and outwards and then curves backwards and outwards instead of inwards as in the majority of the species hitherto described. Owing to these anatomical relations, one would expect *Petropedetes* to have a long pseudobasal process and a large cranio-quadrate passage, but an examination of the figures shows that the pseudobasal process is hardly differentiated as a separate entity and that the cranio-quadrate passage is reduced to a mere foramen. Both these conditions are due to the fact that the otic process is not rod-shaped as in the European *Rana*, but is an obliquely inwardly directed blade of cartilage, which is confluent with the ventral aspect of the crista parotica as well as with the cartilage forming the anterior wall of the fossa fenestræ vestibuli (Fig. 4c). The anterior part of the pseudobasal process articulates with the ventral part of the otic capsule. The synovial cavity is small, and the connection is chiefly effected by connective tissue (Figs. 3 and 4c). Its middle portion is confluent with the antero-ventral part of the wall of the fossa fenestræ vestibuli (Fig. 4c), and its posterior tip is again syndesmotically connected to the latter. Except for this posterior portion, the pseudobasal process is confluent along its entire length with the otic process. The connexion of the palato-quadrate to the skull is, therefore, rigid, and it must be assumed that the above mentioned synovial cavity is functionless. Apart from minor deviations the suspensorial region is very similar to that of *Arthroleptides*.

De Beer (1926) and Pusey (1938) have shown that the mode of origin of the pseudobasal process and its relation to the palatine nerve in the *Anura* preclude it from being homologised with the basal process of other vertebrates.

The pterygoid is a well-developed membrane bone applied to the ventral, median and dorsal sides of the pterygoid process. At the approaches to the suspensorial region it also invests the dorso-lateral border of the process. It not only invests, but also invades the anterior part of the pseudobasal process (Figs. 4b and 5b) as in *Arthroleptides* and a few other *Anura*. Owing to the peculiar relations of the processes of the palato-quadrate described above, that part of the pterygoid underlying the pseudobasal process is remarkably long (Fig. 5).

In the articular region the quadrato-jugal invests the pars quadrata. The connective tissue separating the two entities disappears, and the bone invades the cartilage, thus simulating perichondral ossification of the latter (Fig. 4d).

## The Lower Jaw.

The only interesting feature of an otherwise normal lower jaw is the articular region of Meckel's cartilage, whose peripheral part is weakly ossified perichondrally and more strongly enchondrally. Small marrow cavities are present in the region of the enchondral ossification. There is no reason why this ossification should not be regarded as an articular, the occurrence of which is rare among the *Anura*. In *Petropedetes johnstoni* no trace could be found of the "sharp tooth-like process at the symphysial extremity of each ramus of the mandible," which Boulenger (1905) described in the male of *P.natator*..

## Hyoid Apparatus.

The hyoid apparatus agrees in its essential features with that of the European *Rana*. The hyale is confluent with the otic capsule in close proximity to that region where the plectrum is fused to it.

## Summary.

1. A comparison of the skull of the juvenile with that of the adult reveals interesting growth changes manifested by a relative decrease in the size of the chondro- and viscero-cranial structures and by a corresponding increase in the size of the dermal bones.

2. Except for the absence of a lateral wall, the olfactory capsule is essentially Ranid in structure.

3. The recessus sacciformis is represented only by a small infundibular recess.

4. Only the anterior vestibular " Wulst " is present.

5. The plica obliqua is suspended from the tectum.

6. The cavum principale has a small ventro-median recess accompanied by a glandula oralis interna.

7. The anterior part of the " Rachendrüse " consists of a median and a lateral division each having its own opening into the buccal cavity.

8. The premaxillary and the maxillary are dentigerous.

9. The maxillary has a large palatal process.

10. The vomer is divided into an anterior and a posterior part; the latter, which is dentigerous, fuses with the palatine.

11. The brain-case with its associated dermal bones is typically Ranid.

12. The processus ascendens partis externæ plectri is ligamentous.

13. The annulus tympanicus is ring-shaped.

14. *Petropedetes* is unique in possessing a seasonal secondary sexual characteristic in the form of the tympanic papilla.

15. The pseudobasal and otic processes differ from those of the European *Rana*.

16. The cranio-quadrate passage is reduced to a foramen.

17. The pterygoid invades the anterior part of the pseudo basal process.

18. An articular is present in the lower jaw.

19. The hyale is confluent with the otic capsule.

BIBLIOGRAPHY.

BOULENGER, G. A.: "A List of Reptiles and Batrachians collected by Mr. H. H. Johnston on the Rio del Rey, Cameroons District, W.Africa." *Proc.zool.Soc.Lond.*, p. 564 (1887).

BOULENGER, G. A.: "A List of the Batrachians and Reptiles of the Gaboon (French Congo), with Descriptions of new Genera and Species." *Proc.zool.Soc.Lond.*, p. 433 (1900).

BOULENGER, G. A.: "Descriptions of new West-African Frogs of the Genera Petropedetes and Bulua." *Ann.Mag.Nat.Hist.*, 7th ser., **15**: 281 (1905).

DE BEER, G. R.: "Studies on the Vertebrate Head. II. The Orbito-temporal Region of the Skull." *Quart.J.micr.Sci.*, **70**: 263 (1926).

DU TOIT, C. A.: "Die Skedelmorphologie van Heleophryne regis." *This Journal*, **27**: 426 (1930).

DU TOIT, C. A.: "'n Korreksie van my Verhandeling oor die Skedelmorphologie van Heleophryne regis." *This Journal*, **28**: 408 (1931).

DU TOIT, C. A.: "Some Aspects of the Cranial Morphology of *Rana grayi* Smith." *Proc.zool.Soc.Lond.*, p. 715 (1933).

DU TOIT, C. A.: "The Cranial Morphology of *Crinia georgiana* Tschudi (Cystignathidæ, Amphibia)." *Proc.zool.Soc.Lond.*, p. 119 (1934).

DU TOIT, C. A.: "The Cranial Anatomy of *Arthroleptides dutoiti* Loveridge." *Anat.Anz.*, **86**: 388 (1938).

FOSKE, H.: "Das Geruchsorgan von Xenopus laevis. *Z.Anat. Entwgesch*, **103**: 519 (1934).

GAUPP, E.: A. Ecker's und R. Wiedersheim's Anatomie des Frosches. Auf Grund eigener Untersuchungen durchaus neu bearbeitet. Erste Abteilung, 1896. Zweite Abteilung, 1899. Dritte Abteilung, 1904. Vieweg und Sohn, Braunschweig.

HELLING, H.: "Das Geruchsorgan der Anuren, vergleichend-morphologisch betrachtet." *Z.Anat.Entwgesch*, **108**: 587 (1938).

MÜLLER, E.: "Untersuchungen über die Mundhöhlendrüsen der anuren Amphibien." *Morph.Jb.*, **70**: 131 (1932).

NOBLE, G. K. and PARKER, H. W.: "A Synopsis of the Brevicipitid Toads of Madagascar." *Amer.Mus.Novit.*, No. 232, p. 1 (1926).

NOBLE, G. K.: The Biology of the Amphibia. McGraw-Hill, New York (1931).

PARKER, H. W.: "Parallel Modifications in the Skeleton of the *Amphibia Salientia*." *Arch.zool.ital.*, **16**: 1239 (1931).

PARKER, H. W.: "The Amphibians of the Mamfe Division, Cameroons. —1. Zoogeography and Systematics." *Proc.zool.Soc.Lond.*, p. 135 (1936).

PUSEY, H. K.: "Structural Changes in the Anuran Mandibular Arch during Metamorphosis, with reference to *Rana temporaria*." *Quart.J.micr.Sci.*, **80**: 479 (1938).

REICHENOW, A.: "Eine Sammlung Lurche und Kriechthiere von West Afrika." *Arch.Naturgesch.*, **Jhg.40, 1**: 287 (1874).

SANDERSON, IVAN T.: "The Amphibians of the Mamfe Division, Cameroons.—II. The Ecology of the Frogs." *Proc.zool.Soc. Lond.*, p. 165 (1936).

SCHOONEES, D. A.: "Die Skedelmorphologie van Bufo angusticeps (Smith)." *This Journal*, **27**: 456 (1930).

STADTMULLER, F.: "Kranium und Visceralskelett der Stegocephalen und Amphibien." *Hb.vergl.Anat.Wirbt.*, herausgeg. von Bolk, Goppert, Kallius und Lubosch, **4**: 501, (1936).

## FIGURES AND ABBREVIATIONS.

Fig. 1: Transverse section through the anterior part of the olfactory capsule.

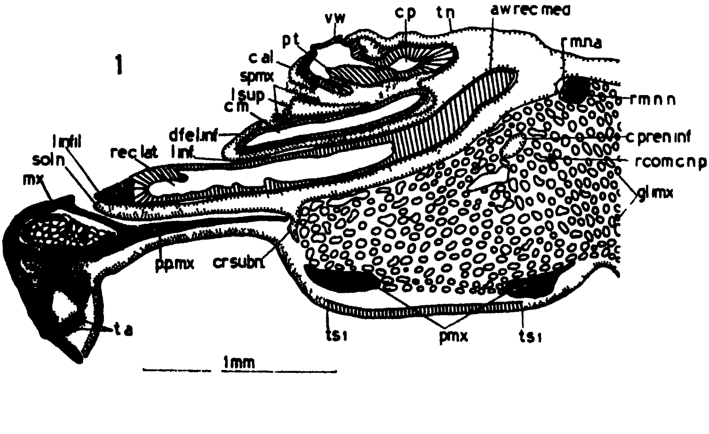
Fig. 2: Transverse sections through the olfactory capsule in the region of the " Rachendrüse ": a, showing the duct of the lateral division; b, of the median one, as well as the duct of the reservoir; and c, the reservoir itself.

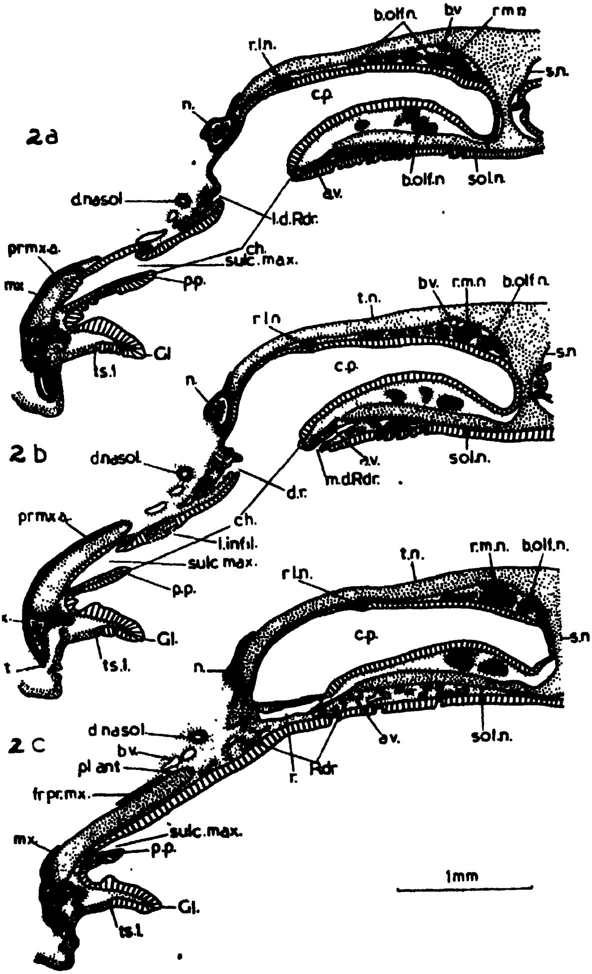
Fig. 3: Antero-dorsal view of the otic capsule and suspensorial region of the left side.

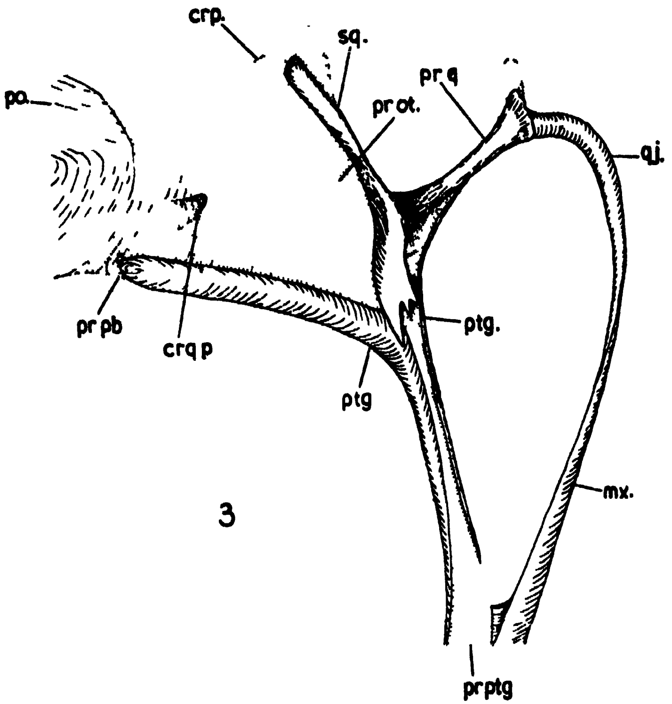
Fig. 4: Transverse sections through the suspensorial region and sound conducting apparatus of the left side: a, showing the invasion of the pseudobasal process by the pterygoid; b, the attachment of the pseudobasal process to the palatoquadrate; c, the pseudobasal articulation; and d, the fusion of the hyale to the otic capsule.

Fig. 5: Transverse sections showing the tympanic papilla: an.t., annulus tympanicus; a.v., anterior division of vomer; a.w.rec.med., anterior wall of the recessus medialis; b.olf.n., branches of the olfactory nerve; b.v., blood vessel; c.al., cartilago alaris; ch., choana; c.m., cavum medium; c.p., cavum principale; c.pren.inf., cartilago praenasalis inferior; cr.p., crista parotica; crq.p., cranio-quadrate passage; cr.subn., crista subnasalis; d.f.e.l.inf., dorsally flexed edge of the lamina inferior; d.nasol., ductus nasolacrimalis; d.r., duct of the reservoir of the " Rachendrüse "; E.t., Eustachian tube; f.ac.ant., foramen acusticum anterius; fp., frontoparietal; f.po., foramen prooticum; fr.pr.mx., frontal process of the maxillary; g., gonial; g.po.com., ganglion prooticum commune; gl., gaumenleiste; gl.imx., glandula intermaxillaris; hy., hyale; i.e., internal ear; i.p.ext.pl.,

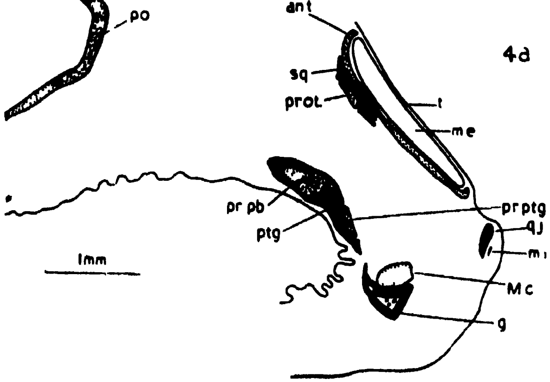
insertion of pars externa plectri; l.d.Rdr., duct of the lateral division of the "Rachendrüse"; l.inf., lamina inferior; l.infil., lymphoid infiltration; l.sup., lamina superior; M.c., Meckel's cartilage; m.d.Rdr., duct of the median division of the "Rachendrüse"; m.e., middle ear; mx., maxillary; n., nasal; p.ext.pl., pars externa plectri; p.int.pl., pars interna plectri; p.m.pl., pars media plectri; p.p., plica palatina; p.p.mx., palatal process of the maxillary; p.t., plica terminalis; pl.ant., planum antorbitale; pmx., premaxillary; po., prootic; pr.as.p.ext.pl., processus ascendens partis externae plectri; pr.mx.a., processus maxillaris anterior; pr.ot., processus oticus; pr.pb., processus pseudobasalis; pr.ptq., processus pterigoideus; pr.q., processus quadratus; ps., parasphenoid; ptg., pterygoid; qj., quadratojugal; r., reservoir of the "Rachendrüse"; r.com.c.n.p., ramus communicans cum nervo palatino; r.hy., ramus hyomandibularis; r.l.n., ramus lateralis narium; r.m.n., ramus medialis narium; r.m.n.a., ramus medialis narium of the arteria orbitonasalis; r.m.n.n., ramus medialis narium of the ophthalmic nerve; r.mx.mn., ramus maxillo-mandibularis; r.p., ramus palatinus; Rdr., "Rachendrüse"; rec.lat., recessus lateralis; s.n., septum nasi; sol.n., solum nasi; sq., squamosal; sulc.max., sulcus maxillopalatinus; t., tooth, tympanum; t.a., tooth-anlage; t.n., tectum nasi; t.p., tympanic papilla; ts., transition between the stratified epithelium of the upper lip and the columnar epithelium of the buccal cavity; v.c.l., vena capitis lateralis; v.j.i., vena jugularis interna; v.w., Vestibular wall.



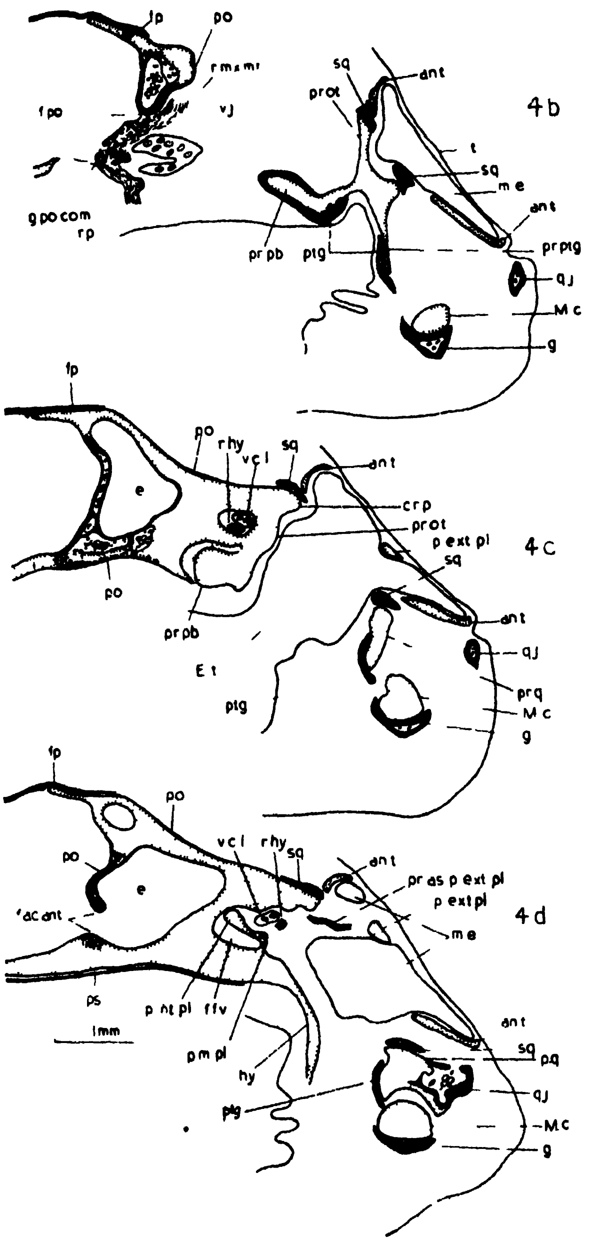

2a
b.olf.n.
bv
r.m.n
r.l.n.
s.n.
n.
c.p.
b.olf.n
sol.n.
d.nasol.
a.v.
l.d.Rdr.
prmx.a.
ch.
sulc.max.
mx
p.p.
Gl.
ts.l
2b
bv.
r.m.n
b.olf.n.
t.n.
r.l.n
s.n
c.p.
n.
d.nasol.
a.v.
sol.n.
m.d.Rdr.
d.r.
prmx.a.
ch.
l.inf.l.
sulc.max.
p.p.
Gl.
ts.l.
t
2c
t.n.
r.m.n.
b.olf.n.
r.l.n.
c.p.
s.n
n.
d.nasol.
a.v.
sol.n.
b.v.
pl.ant.
r.
Rdr
fr.pr.mx.
sulc.max.
mx.
p.p.
1mm
Gl.
ts.l.

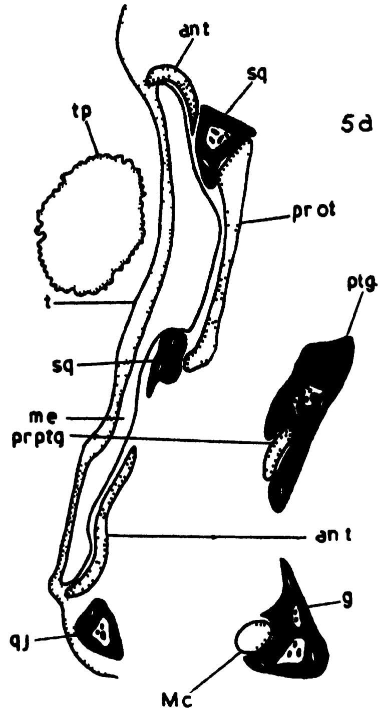

crp.
sq.
pr q
pr ot.
po.
qj.
pr pb
crq p
ptg.
ptg
mx.
pr ptg

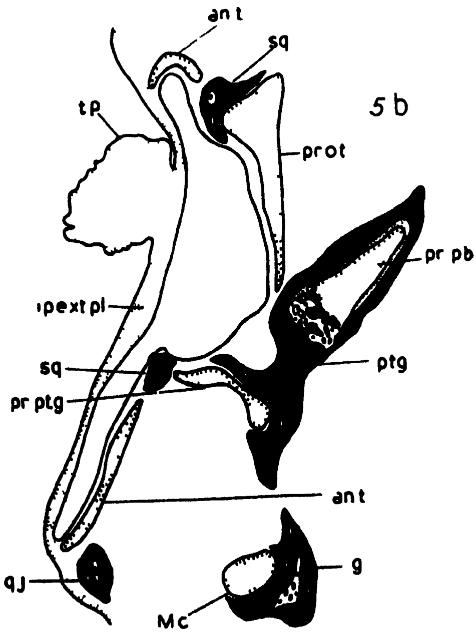
3


fp
po
ant
sq
prot.
t
me
pr pb
ptg
pr ptg
qj
m1
Mc
g
1mm

4a


fp
po
r mx mi
vj
f po
g po com
rp
sq
prot
ant
4 b
t
sq
m e
ant
pr ptg
pr pb
ptg
qj
M c
g
fp
po
r hy
v c l
sq
ant
e
c r p
prot
p ext pl
4 c
sq
po
ant
pr pb
qj
E t
pr q
ptg
M c
g
fp
po
po
v c l
r hy
sq
ant
pr as p ext pl
p ext pl
4 d
e
m e
ps
ffv
1mm
ant
sq
pq
p m pl
hy
qj
ptg
M c
g


ant
sq
5a
tp
prot
ptg
t
sq
me
prptg
ant
g
qj
Mc


ant
sq
5b
tp
prot
pr pb
pextpl
ptg
sq
pr ptg
ant
g
qj
Mc

South African Journal of Science, *Vol. XL, pp. 213-219, November, 1943.*

# A FURTHER CONTRIBUTION TO THE THIGH MUSCULATURE OF CERTAIN ETHIOPIAN RANIDS

BY

C. S. Grobbelaar,

*Zoological Institute, University of Stellenbosch.*

*With 4 Text-figures.*

*Read 29th June, 1943.*

## Introduction.

There exists a good deal of confusion regarding the taxonomic position of several of the genera belonging to that group of Ethiopian Ranids which, on account of their smallness and apparent external similarity, will for the sake of convenience be called the "Microranids." The use of this term does not imply any genetic relationship between them, nor should it be regarded as having any systematic significance.

The present investigation must in the first place be regarded as a contribution to the thigh musculature of the species examined. Noble (1922, 1931) in his investigation of the thigh musculature of the *Anura* came to the conclusion that the different relations of certain thigh muscles, and the different manner in which they are inserted on the knee-joint are distinctive features of the different orders of the *Anura*. According to him "the *musculus semitendinosus* is distinct from the *m. sartorius*, and its distal tendon passes dorsal to the distal tendon of the *gracilis* mass" in all diplasiocœlous ranids (*op. cit.*, 1931, p.514). In this investigation the term "ranid type" will be used in the sense that Noble used it. At this stage no attempt will be made to deny or corroborate Noble's assertion that the manner of insertion of certain muscles of the thigh is of diagnostic value in defining the different orders. That will only be possible when the results of this investigation are correlated with those of previous workers on the same group and with those of similar investigations that are now in progress in this Institution.

## Material and Technique.

The material used was preserved in 5 per cent. formalin, and taken from the collection of *Anura* in the Zoological Museum of this Institution. *Petropedetes johnstoni* was obtained from Mr. F. R. Parrington, Director of the University Museum, Cambridge. The outline drawings were made with the aid of a camera lucida. Owing to the small size of most of the

specimens, it was necessary to carry out the dissections under water under a low power microscope. The *gracilis minor* acquired in many cases such a close connection with the skin that it was often necessary to apply a few drops of concentrated hydrochloric acid to the skin around the anus and wash in water to determine whether the muscle actually arises from the skin (Bigalke, 1926). The nomenclature adopted is that laid down by Gaupp (1896-1904).

The following species were examined—the number in brackets after each denotes the length in millimetres.

*Anhydrophryne rattrayi* (18); *Arthroleptis minutus* (21); *A.wageri* (32); *A.adolfi-friederici* (36); *A.reichei* (29); *Arthroleptella* sp. (16); *Arthroleptides martienssensi* (23); *Cacosternum capense* (34;) *C.boettgeri* (23); *C.namaquense* (19); *C.boettgeri* var. *albiventer* (17); *Microbatrachella capensis* (14); *Microhyla carolinensis* (32); *Phrynobatrachus kinangopensis* (21); *Petropedetes johnstoni* (53).

Only those thigh muscles which, according to Noble (*op. cit.*, 1922), have a phylogenetic bearing will be discussed. Detailed descriptions of the thigh muscles together with their innervations have been given by Gaupp (*op. cit.*) for *Rana*, by Nussbaum (1898) for several other genera, and by Beddard (1908), Noble (*op. cit.*, 1922) and Bigalke (*op. cit.*).

## The Thigh Muscles.

*Sartorius* and *adductor longus*.

The relations of these two thin, flat muscles to each other vary considerably. Three types of variation were observed.

1. The *adductor longus* arises almost in front of the *sartorius*, and the two lie side by side in *Arthroleptis minutus* and *Microhyla carolinensis*. A similar condition obtains in *Phrynobatrachus kinangopensis* (Nel, 1941).

2. At its origin and along its posterior margin it is partly or almost completely covered by the *sartorius* in *Cacosternum* spp. (Fig. 1), *Arthroleptis reichei* and *Anhydrophryne rattrayi* (Fig. 2), and in *Arthroleptella bicolor* (Nel, *op cit.* Fig. IX). In *Arthroleptis reichei* some of the posterior fibres of the *sartorius* fuse distally with the *caput ventrale* of the *adductor magnus*. In *Arthroleptella bicolor* some of the distal fibres are inserted on the anterior margin of the *gracilis major*.

3. At its origin and along its entire length it is entirely covered by the *sartorius* in *Microbatrachella capensis*, *Petropedetes johnstoni* (Fig. 3) and *Arthroleptides martienssensi*. The very small size of the *adductor longus* in the latter two species is very significant.

My observations on *Microbatrachella capensis*, *Cacosternum* spp., and *Anhydrophryne rattrayi* agree very nearly with those of Nel (*op. cit.*).

*Adductor magnus*.

The relations of the *caput dorsale* to the *gracilis major* can be summarised as follows:

1. Proximally the anterior margin of the *gracilis major* entirely covers the *caput dorsale* in *Anhydrophryne rattrayi, Phrynobatrachus kinangopensis, Arthroleptis* spp., and *Arthroleptella bicolor*.

2. It covers the greater part of the *caput dorsale* in *Cacosternum* spp., *Microhyla carolinensis* and *Arthroleptis wageri*.

3. It does not cover it (as in *Rana*) in *Petropedetes johnstoni* and *Arthroleptides martienssensi*.

There is a third or accessory head to the *adductor magnus* in *Microbatrachella capensis* and *Arthroleptella bicolor* in which it consists of a few fibres only; a distinct accessory head in *Cacosternum capense* and *C. namaquense* (absent in *C. boettgeri*), in *some* species of *Arthroleptis* e.g. *A. adolfi-friederici;* a well-developed head (as in *Rana* e.g *R. fuscigula*) in *Petropedetes johnstoni* and *Arthroleptides martienssensi*.

*Gracilis major.*

The presence of an inscriptio tendinea running obliquely through it at any point between the proximal and distal third of its length, is characteristic of the *gracilis major*. The relations of this muscle were found to be similar to those in *Rana*, except that in *Anhydrophryne rattrayi* the inscriptio tendinea runs ventrally over its whole length apparently dividing it into two halves.

*Gracilis minor.*

In species of *Arthroleptis*, in *Cacosternum* spp. (but not in *C. boettgeri* var. *alliventer*) this slender muscle consists of an anterior and posterior slip. The former arises in the usual way, ventral to the *gracilis major* from the outer surface of the pubic symphysis, anteriorly to the *rectus abdominis*, and posteriorly to the skin below the *compressor ani*, in some cases it arises like the fibres of the posterior slip from the thin tendon running from the pubic symphysis. After attaching themselves to the skin. the fibres of both slips lose their skin attachment, and together with the *gracilis major* insert ventrally on the head of the tibia.

In *Phrynobatrachus kinangopensis* and *Arthroleptella bicolor* a similar condition obtains, but the fibres of the posterior slip definitely arise from the skin immediately below the *compressor ani*. In *Anhydrophryne rattrayi* and *Microhyla carolinensis*, the *gracilis minor* is merely a thin flat muscle which arises from the pubic symphysis, attaches itself to the skin and thence proceeds as a thin strip of muscle to insert with the *gracilis major*.

In *Microbatrachella capensis* the *gracilis minor* is a mere bundle of fibres originating from the skin below the *compressor ani*. The *gracilis minor* is a single, flat muscle in *Petropedetes johnstoni* and *Arthroleptides martienssensi*. In both, the origin has shifted backwards and cannot be observed from the ventral

surface. In *Petropedetes johnstoni* it arises from the posterior edge of the *compressor ani*, from the fibres by which that muscle is connected with the skin round the anal opening. In *Arthroleptides martienssensi*, it takes its origin below the *compressor ani* from the posterior extension of the ligament which runs from the pubic symphysis to the *rectus abdominis*. In all the remaining species the condition is the same as in *Rana*.

*Semitendinosus.*

The sinking of the two heads of this muscle deep within the thigh to the position they occupy in *Rana*, is significant of the higher *Diplasiocoela*. Its phylogenetic significance has been emphasised by Noble (*op. cit.* p.30, 1922). For all Ranids he claims that (1) the *gracilis major* and *minor* dip under the tendon of the *Sartorius* to insert on the distal end of the femur, (2) the distal tendon of the *semitendinosus* is free from the *gracilis* mass and is inserted dorsal to the distal tendon of the *gracilis* mass. This condition is illustrated in Fig. 4, which has been drawn from a dissection of *Rana fuscigula*.

All the species examined exhibited this typical *ranid type* of thigh musculature. It was interesting to find that in *Arthroleptis* spp., in *Petropedetes johnstoni* and others, the distal tendon of the *semitendinosus* was so closely applied to the distal tendon of the *gracilis* mass, that one can well imagine a condition where the tendon of the *semitendinosus* actually pierces the *gracilis* mass. This latter condition has been found by Noble for a bufonid *Pleuroderma bibroni*. The ranid type of musculature in *Arthroleptella* was referred to by de Villiers (1929). In his short reference to it, he does not accentuate the real nature of this type of musculature, as explained by Noble (*op. cit.*). The species in which the *semitendinosus* gives off an accessory head of the *adductor magnus* have already been mentioned. The two heads, the origins of which are well known (Gaupp *op. cit.*) are usually more or less of the same size, and fuse distally. The only case in which a remarkable variation exists is in *Arthroleptis adolfi-frederici*, where the dorsal head is principally a tendinous thin ribbon throughout with a very short belly on the proximal third. In *Cacosternum* spp. the sinking in of this muscle has gone so far, that its distal portion lies exposed between the *gracilis* mass and the *semimembranosus*. According to Nel (*op. cit.*) a similar condition obtains in *Microbatrachella capensis* and *Arthroleptella bicolor*, its exceedingly long tendon in *Petropedetes johnstoni* (Fig. 3) and *Arthroleptides martienssensi* is very significant.

*Triceps femoris* (=*tensor fasciae latae*, *cruralis* and *glutaeus*).

A *tensor fasciae latae* was present in all the species examined. Its size varies, but not to such an extent as to warrant special consideration. An accessory head of the *cruralis* is present in *Cacosternum capense* and *C. namaquense* (but not in *C. boettgeri*), in *Microhyla carolinensis* and *Microbatrachella capensis*. This splitting off of an accessory head of the *cruralis*

is incipient in *Rana* (Gaupp *op. cit.*), in Bufonids (Noble *op. cit.*, 1922, Bigalke *op. cit.*) and in Pelobatids (Nussbaum *op. cit.* p.381).

*Iliacus externus* AND *Iliacus internus*.

"All families of frogs and toads above the discoglossids, pipids and pelobatids lack the accessory head of the iliacus *externus*" (Noble *op. cit.* p.28). Although it would be incorrect to speak of an accessory head of the *iliacus externus* in *Cacosternum boettgeri* and *C. namaquense*, it is interesting to note that in these two species this muscle arises dorsally on the ilium, as in *Bufo vulgaris* (Bigalke *op. cit.*), and not laterally as in *Rana* (Gaupp *op. cit.*). Distally there is an incipient splitting off of an accessory head inserting on the proximal end of the femur immediately in front of the insertion of the bulk of the muscle itself.

In none of the species examined was there an accessory head to the *iliacus internus*.

## DISCUSSION.

To decide whether slight variations in origin, insertion and size in the thigh musculature of the Microranids have any taxonomic value, it is necessary to bear in mind that each of the following pairs of muscles: *Cruralis* and *glutaeus*, *pectineus* and *adductor longus*, *sartorius* and *semitendinosus*, *gracilis major* and *gracilis minor*, was a single muscle in the primitive Salientia (Noble *op. cit.*, 1922).

We cannot conclude that in the Microranids a greater degree of fusion between any pair of these muscles denotes a less specialised, and a lesser degree of fusion, a more specialised condition. In *Cacosternum capense* and *C. namaquense* and in *Arthroleptella* there is a greater fusion between the *cruralis* and the *glutaeus* than in *Microbatrachella capensis*. If this means a less specialised condition in the two species of *Cacosternum*, it at once becomes more specialised on account of the presence of an accessory head to the *cruralis*. The same type of argument would apply to *Microbatrachella capensis* in which also there is an accessory head to the *cruralis*.

I found that the same type of variations in the thigh muscles may occur in species belonging to different genera. These variations can, therefore, have no taxonomic significance for determining species. But it can be definitely stated that in the Microranids examined there is a ranid type of thigh musculature as defined by Noble for all diplasiocoelous *Salientia*.

## BIBLIOGRAPHY.

BEDDARD, F. E.: "On the Musculature and other Points in the Anatomy of the Engystomid Frog, *Breviceps Verrucosus*." *Proc. Zool.Soc.Lond.*, p. 11 (1908).

BIGALKE, R.: "Zur Myologie der Erdkröte." *Z.ges.Anat.* Abt. I. 82: 288 (1926).

DE VILLIERS, C. G. S.: "The Development of a Species of Arthroleptella from Jonkershoek, Stellenbosch." *This Journal.* **26**: 481 (1929)

GAUPP, E.: A. Ecker's und R. Wiedersheim's Anatomie des Frosches. 3v. 1896-1904. Vieweg und Sohn, Braunschweig.

NEL, P. S.: "Some Aspects of the Thigh Musculature of Certain Microranid Genera." *Ann.Univ.Stell.*, Sect. A, **19**: 1 (1941).

NOBLE, G. K.: "The Phylogeny of the Salientia I.—The Osteology and the Thigh Musculature; Their Bearing on Classfication and Phylogeny." *Bull.Amer.Mus.Nat.Hist.* **46**: 1 (1922).

NOBLE, G. K.: The Biology of the Amphibia. McGraw-Hill, New York, 1931.

NUSSBAUM, M.: "Nerv und Muskel. II. Der Oberschenkel einiger anuren Batrachier." *Arch.mikr.Anat.*, **52**: 367 (1898).

## FIGURES AND ABBREVIATIONS

Fig. 1: Thigh muscles of *cacosternum capense.* Ventral view.

Fig. 2: Thigh muscles of *Anhydrophryne rattrayi.* Ventral view.

Fig. 3: Thigh muscles of *Petropedetes johnstoni.* Ventral view.

Fig. 4: Ventral view of the thigh muscles of *Rana fuscigula* (partly schematised) to illustrate the "ranid type" of thigh musculature: add.long., adductor longus; add.mag.acc.head, adductor magnus accessory head; add.mag.cap.dors., adductor magnus caput dorsale; add.mag.cap.vent., adductor magnus caput ventrale; attach. to skin, attachment to skin; crur., cruralis; grac.maj., gracilis major; grac.min., gracilis minor; pect., pectineus; sart., sartorius; semiten.-dors, semitendinosus caput dorsale; semiten-cap.vent., semitendinosus caput ventrale; tend.grac., tendon of gracilis mass; tend.semiten., tendon of semitendinosus.

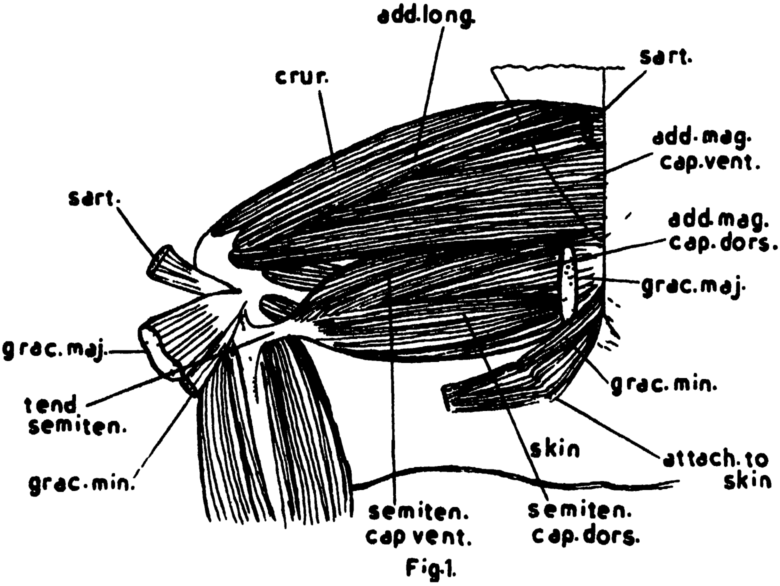



Fig.1.

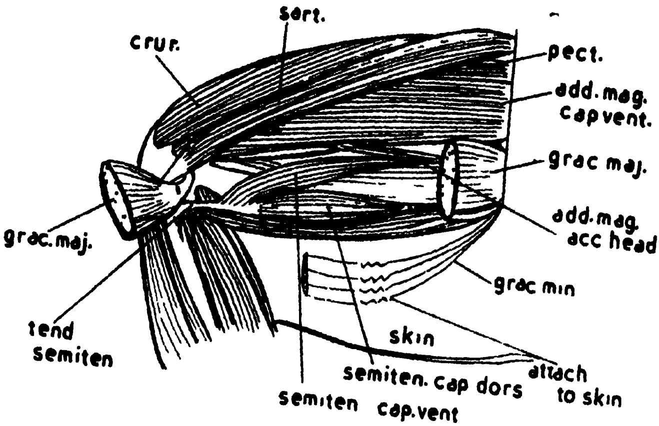



Fig 2.

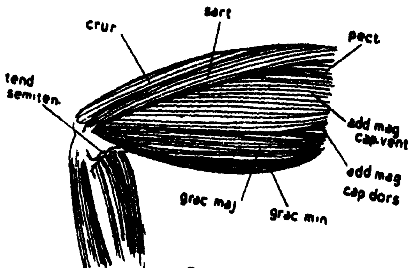



Fig 3

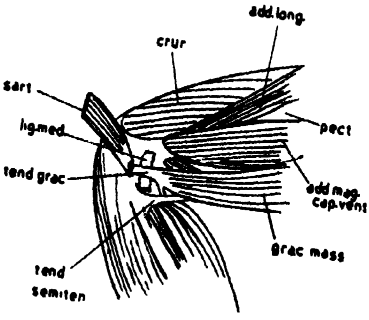



Fig. 4

South African Journal of Science, *Vol. XL, pp. 220-225, November, 1943.*

# THE ANATOMY OF HUMAN SEMINIFEROUS TUBULES

BY

G. H. Findlay,

*Department of Anatomy, University of the Witwatersrand.*

*With Text-figure.*

*Read 29th June, 1943.*

During the past fifty years textbooks of anatomy have given essentially the same account of the structure of the testis. The description which follows is taken from Frazer (1937) and may be regarded as typical:

> " The mediastinum testis. . . extends into the organ for one fourth of its anteroposterior measurement, and from its sides and anterior border a number of septa. . . pass off, which extend in various directions as far as the inner surface of the tunica albuginea, to which they are attached. By means of these the interior of the testis is mapped out into a number of lobes. . . These compartments contain the convoluted seminiferous tubules collected into bundles called lobes of the testis which vary in number from 100 to 200. Each lobe contains from two to four tubules. . . When the coils are undone the tubule measures about two feet in length. The tubules of each lobule unite into one, and the tubules of adjacent lobules unite in turn, and so give rise to straight tubules. . . These straight tubules enter the mediastinum, where they form the rete testis."

This description implies that the testis is a compound tubular gland. However, the studies of Huber and Curtis (1913) on the rabbit, and those of Bremer (1911) and Johnson (1934) on the human foetus and adult respectively, all indicate that the tubules are not arranged in this way. It has, therefore, appeared worth while to make a new examination of the tubule pattern.

## Material and Methods.

The testes used were those of South African Negro adults. Except for one unfixed testis, they were taken from dissection-room cadavers fixed by formalin injection. The tubules were studied by gross dissection. Johnson (1934) devised a preparatory maceration technique to facilitate dissection; this, however, had to be considerably modified to suit my material. After removal from the body the fixed testes were kept in 10 per cent formalin until they were needed for dissection. The tunica

albuginea was carefully stripped back to the mediastinum, and the exposed tubules immersed for two or three hours in 25 per cent hydrochloric acid. This procedure was found to dissolve the interstitial tissue without softening the tubules. In some testes the tubules had become softened before treatment was started, and these could not be dissected. The fresh testis was kept in normal saline solution for 18 hours after removal from the body. When the tunica albuginea was dissected back, teasing was found to be impossible because the tubules were surrounded by a highly viscous interstitial fluid (or "tissue"); immersion in 25 per cent hydrochloric acid for a minute freed the tubules from their matrix.

After maceration the testes were washed and the tubules teased in air under a binocular dissection-microscope. Tubules were picked up on the surface and traced; their direction and branchings were mapped. In this way the tubuli recti, being approached from their distal ends, were less readily broken. Provided the tubules were kept moist, it was found better to dissect in air; in water they float freely and one frequently loses the thread.

By this method the testis need not be cut.

Johnson considers it possible to distinguish between diverticula and broken tubules by careful inspection. This I found extremely difficult, since there appeared to be no clear difference between genuine diverticula (placed where one could safely suppose that the tubule had not been strained to breaking-point) and broken tubule branches.

## OBSERVATIONS.

Figures 1-3 show the principal features of the tubule morphology. Only the branchings and approximate lengths are indicated, and no attempt has been made to reproduce the contortions which merely obscure the pattern. Other dissections showed patterns not essentially different from these.

Anastomosis between convoluted tubules is widespread, and takes place in all directions; circular anastomoses (Fig. 1a) were frequent in the more extensive dissections. However, no circle has fewer than three tubules leading from it (Fig. 3b) and more commonly there are four or more. Relatively straight tubules are sometimes seen lying between bundles of contorted tubules. The local narrowings described by Johnson were not seen. Diverticula were more common in some testes, but were less common in my material than in Johnson's. A group of local dilatations was once seen. These are the ampullae of Eberth, and their position is marked in Fig. 2. No unbranched, blindly ending tubules were found, and the only tubule completely unravelled was a simple arch. (Fig. 3c).

The tubuli recti are short, translucent channels, somewhat thinner than the tubuli contorti which they connect to the

mediastinum. Macroscopically they appear to be prolongations of the rete testis. They are sometimes Y-shaped, and a contorted tubule is connected to each prong of the Y, as seen in Fig. 3a. Diverticula at the junction between straight and contorted tubules, such as Johnson described, were not found.

Septa are imperfect and irregular. Lobules are not completely separated from neighbouring lobules, and the statement that there are between two and four tubules in each lobule is incorrect. A lobule consists of only a part of a contorted tubule complex in a relatively separate connective-tissue sheath. Each limb of the tubule-arch shown in Fig. 3c was gathered into a " tubule-bundle " or lobule of the testis. (It should be noted that the terms " lobe " and " lobule " are apparently interchangeable.)

## Discussion.

Johnson (1934) showed that the tubules of the human testis form a series of arcades, as found in the rabbit by Huber and Curtis (1913). But instead of the anastomosis being simply a " two-dimensional " one, my preparations have shown that it takes place in all directions. Many complete circular anastomoses are present. These are recorded in a diagram given by Fort (1871) which is reproduced in Fig. 4a. I have not found this arrangement as clearly represented in any more recent text on the human testis.

Bremer (1911) made wax reconstructions of foetal testis tubules, and found them to be arranged as arcades of connecting radial cords, with transverse connections in all directions. He believed that this pattern became largely obliterated in later development. My findings show the adult structure to be not very different from the foetal plan. The obliteration is at least not as extensive as Bremer had supposed. Bremer also speaks of tubules (believed to represent the radial cords of the developing testis) which run with a slight wavy course from the rete to the peripheral convoluted portion. They occur in my preparations, and do not otherwise differ from true tubuli contorti. These structures are evidently what Sappey (Latarjet, 1931) regards as " tubuli recti," in that they are gathering tubules of straight direction.

The modern use of the term " tubulus rectus " has been outlined with the observations, but it is as well to point out that at one time it appears to have referred to something quite different. Alexander Monro (Fyfe, 1801) and Astley Cooper (Morton and Cadge, 1850) called the tubules between the mediastinum and the epididymis the vasa recta, i.e. rete testis plus ductuli efferentes. The name " rete testis " was then applied to the upper posterior part of the gland where these vasa lie.

The arrangement of the testicular tubules as demonstrated by this study is thus widely different from the description still current in textbooks. Further, it resembles in no way the

structure of a compound tubular gland. The origin of the textbook account is obscure since the literature is not accessible, but it appears that Lauth and Krause were the chief contributors. Their papers, which are over a hundred years old, have been referred to by other writers, but were not available. Besides this, Astley Cooper published a woodcut for his work on the testis in 1830 (see Fig. 4b) which has been used and modified to illustrate the textbook description. It may be fairly called misleading, since it fails to represent, even diagrammatically, the testis as it is actually built.

Cowdry (1938) has remarked, concerning the work of Huber and Curtis, that the peculiar arches in the tubules of the testis are without parallel in the body. This view may be justified when one takes, for one's comparison, the glands of external and internal secretion. But the testis is not really comparable with ordinary glands, since it is a " cytogenic " organ of mesodermal origin. It has no greater title to the term " gland " than have either bone marrow or lymph nodes, which also produce cells and are derived from mesoderm. The similarity between spermatogenic and haemopoietic tissues goes further. The capillaries of the vascular area of the yolk-sac, for example, are mesodermal and " cytogenic," and when new capillaries are formed, as in granulation tissue, they develop in arcades with cross-anastomoses exactly as do the testis tubules. A close analogue of the testis may therefore be sought in vascular structures rather than amongst ordinary glands, where little indeed can be found to resemble the tubuli contorti.

## Acknowledgements.

I wish to thank Professor R. A. Dart, head of the department where this work was done. I also wish to thank Drs. L. H. Wells and A. G. Oettlé whose generous help I have much appreciated.

## Summary.

Most accounts of the morphology of the human seminferous tubules are misleading. The tubules form a complex anastomotic meshwork resembling the patterns of newly-formed or embryonic capillaries. Lobules are built up of portions of such systems, and are not formed by separate tubules.

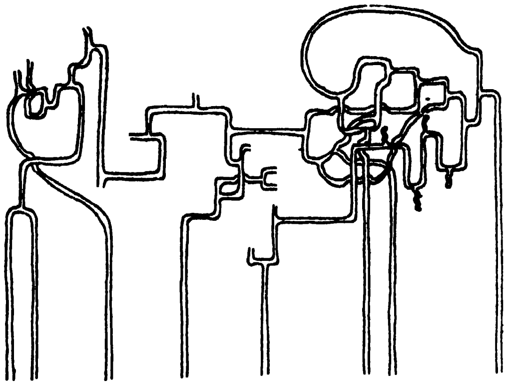
Note.—In the accompanying figures, branches broken or not followed are represented by open tubule ends. Closed tubules represent diverticula.

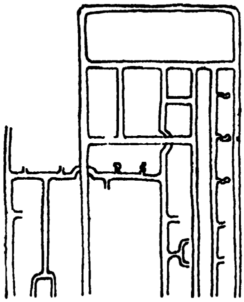
Fig. (1a) Tubule complex which occupied four lobules.

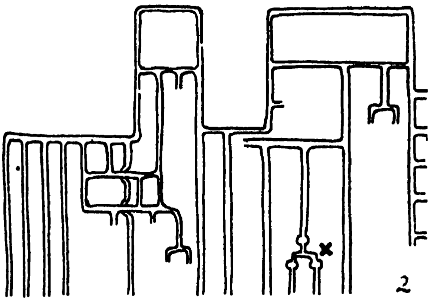
Fig. (1b) The same, arranged to show pattern.

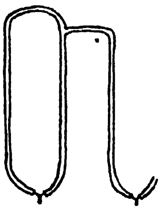
Fig. (2) Tubule complex arranged to show pattern. X shows site of ampullae.

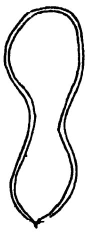
Figs. (3a, b, c) Further dissections, showing tubuli recti.
Fig. (4a) Circular tubule anastomoses (modified from Fort, 1871).
Fig. (4b) Astley Cooper's woodcut (from Morton & Cadge, 1850).

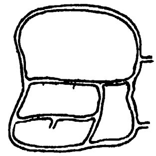

1a

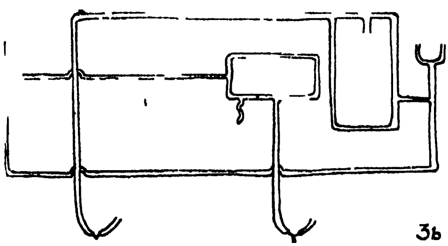

1b

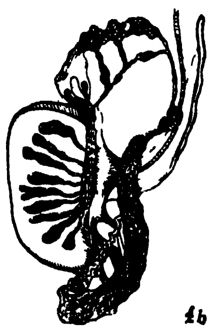

2


3a


3c


4a


3b


4b

## REFERENCES.

BREMER, J. L.: "Morphology of the tubules of the human testis and epididymis." *Am. J. Anat.*, **11**, 393-418 (1911).

COWDRY, E. V.: "A textbook of histology." 2nd ed. Philadelphia: Lea & Febiger (1938).

FORT, G. A.: "Anatomia descrittiva e dissezione." Vol. 3. Milan: Gaetano Brigola (1871).

FRAZER, J. E.: "Buchanan's Manual of Anatomy." 6th ed. Baillière, Tindall & Cox (1937).

FYFE, A.: "A compendium of the anatomy of the human body." 2nd ed. Vol. 2. Edinburgh: Guthrie (1801).

HUBER, G. C. and CURTIS, G. M.: "The morphology of the seminiferous tubules of mammalia." *Anat. Rec.*, **7**, 209-219 (1913).

JOHNSON, F. P.: "Dissections of human seminiferous tubules." *Anat. Rec.*, **59**, 187-199 (1934).

LATARJET, A.: "Testut's Traite d'anatomie humaine." 8th ed. Vol. 5. Paris: Gaston Doin (1931).

MORTON, T., and CADGE, W.: "The surgical anatomy of the principal regions of the human body. Taylor (1850).

# THE RELATIONSHIP BETWEEN HEALTH AND EFFICIENCY

BY

DR. E. JOKL.

*Read 29th June, 1943.*

South African Journal of Science, *Vol. XL, pp. 226-239, November, 1943.*

# THE PANCREAS OF *BOODON LINEATUS*—THE BROWN HOUSE SNAKE

BY

Joan Kristal,

*Department of Anatomy, University of the Witwatersrand.*

*With 5 Text-figures.*

*Read 29th June, 1943.*

## Introduction.

The importance of the pancreas as an organ of external and internal secretion has led to extensive investigations of the gland in mammals and to a lesser extent in lower vertebrates. At the present time, however, comparative studies of the pancreas are infrequent in the literature, especially as regards the reptilian pancreas. The pancreas consists of many cell types, and in order to determine whether these are specific cell types it is necessary to trace their phylogeny as far back as possible. As no study of South African snakes has yet appeared, the common South African snake, *Boodon lineatus*, has been chosen for this study.

Material and Methods: Four specimens of *Boodon lineatus* were available. In each case the pancreas and spleen, being attached to one another, were fixed simultaneously. In two specimens the pancreas was cut transversely into three pieces prior to fixation, while in the remaining two it was cut longitudinally. The latter method of section was found to be most satisfactory, as the greater part of the islet tissue is contained in the splenic end of the pancreas.

The fixation of the pancreas in mammals has always presented certain difficulties, and in the case of the snake, these are accentuated. In order to prevent shrinkage, and to be able to demonstrate adequately the cytoplasmic inclusions, some preliminary fixation experiments were carried out. These are listed in Table 1.

Table 1 shows that Zenker-formol, to which has been added 4cc. normal saline, provides a fixative which causes little shrinkage and gives good fixation of acinar and islet tissue. The addition of saline to cobalt nitrate and formalin reduces shrinkage slightly, but only the zymogen granules and alpha cells in the islets are well preserved. Twenty-four hour fixation with formol or formol-saline gives poor results, but here again the zymogen granules are well fixed. However, this fixative demonstrates the

mitochondria. Therefore, it is possible to conclude that Zenker-formol and saline is the best fixative for acinar and islet tissue. Shrinkage is least marked using this fluid and it is the fixative of choice for cytoplasmic study and nuclear structure, notwithstanding the fact that mitochondria are more in evidence in formol-saline fixed tissue and the Golgi apparatus is demonstrated only by the Da Fano method of fixation and impregnation.

The tissues were dehydrated in alcohol, cleared in chloroform, embedded in wax and sectioned at a thickness of 3 and 4 microns. The routine stains used were:—1. Mallory's triple stain; 2. Azocarmine modification of Mallory's stain; 3. Altmann's Aniline Acid Fuchsin and Methyl Green Stain.

OBSERVATIONS: *Gross Features* (Fig. 1): The pancreas is a small, pale, compact organ measuring approximately 1·25 by 0·75 cm. It is attached by a mesentery to the gut at the level of the pyloro-duodenal junction, and is closely applied to the spleen and the gall-bladder. The spleen lies at the upper pole of the pancreas, and the two organs are enclosed by a thin peritoneal covering. So intimate indeed is the relation beween these two organs in snakes, that Thomas (1942) has demonstrated the presence of pancreatic tissue in the spleen of some American snakes. In one of the specimens used in this study also, small amounts of acinar tissue have been seen in the splenic capsule, and a small accessory pancreas has been observed at the cephalic end of the spleen.

The blood supply of the organ, although easily demonstrated microscopically, is by no means clearly displayed to the naked eye.

*Microscopic Features:* Microscopically the pancreas is essentially the same as that of a mammal, consisting of exocrine and endocrine portions. The gland is divided into lobules by connective tissue trabeculæ traversing it in all directions, and apparently originating from the loose connective tissue capsule, which invests the whole gland. Blood vessels, nerves and ducts are interlobular structures contained within the trabeculæ.

EXOCRINE PORTION (Fig. 2c): The cells comprising this portion are arranged in acini, surrounded by a thin connective tissue layer which forms the basement membrane. The size of the acini is extremely variable, some being formed by as few as five cells, others by as many as twenty cells.

Generally the cells are pyramidal in shape, but the shape is modified during the stages of the secretory cycle. The average cell size, however, is 14. × 8·5 microns.

The cytoplasmic inclusions are distributed in three zones—basal, central and apical. The zymogen granules lie in the apical zone, between a more or less centrally placed nucleus, and the free surface of the cell. As the cell becomes loaded they may fill it completely, pushing the nucleus towards the base. At this stage the cell usually contains many large, round, refractile

granules. Smaller granules of similar dimensions to those found in the guinea pig pancreas, may occur in the early stages of the secretory cycle. The nucleus is a spherical body having a well-defined nuclear membrane. The chromatin is finely granular or in the form of threads, chiefly surrounding the large central nucleolus.

Characteristic of the basal zone of the cell in the house snake is a homogeneous orange-staining substance easily demonstrated by Mallory's stain. Its shape is oval or spherical and the amount in each cell is somewhat variable. This substance has no affinity for Sharlach R, and with Toluidin blue it is demonstrated as a basophilic mass of deeper hue than the basal chromidial substance.

The few mitochondria seen in the specimens are minute rods and filaments lying in the basal zone of the cell. They lie in close apposition to the basal and lateral surfaces of the nucleus. The Golgi apparatus is a small compact network which lies above the nucleus. No Mankowski cells have been observed in any of the specimens.

Duct System: The duct system is similar to that found in any tubulo-alveolar gland. The larger excretory ducts are lined by columnar epithelial cells between which a few goblet cells are interspersed at intervals. It is difficult to distinguish a definite basement membrane, although the ducts are surrounded by a thick band of collagen in which is seen an occasional muscle cell. As the ducts pass more deeply into the substance of the gland the epithelium changes from columnar to cuboidal shape, ending finally in a flattened type of cell, the centro-acinar cell. The collagen investment of the ducts decreases pari-passu with the decrease in size of the duct. The columnar and cuboidal epithelial cells are normal in appearance and the centro-acinar cells have pale homogeneous cytoplasm, and oval, vesicular nuclei containing a nucleolus.

Acinar cells are frequently found forming one side of a duct as is seen in Figs. 2a and 2b. The acini are apparently connected to the duct system in two ways—either they are directly connected to the ducts as tubular outgrowths, or the centro-acinar cells form a means of communication between the two. The centro-acinar cells are observed lying in the lumen of the acini.

There is a system of tubules in the pancreas which has been observed in close relation to both acini and islets. The cells are cuboidal in shape, have an exceptionally clear homogeneous cytoplasm, and spherical or slightly oval nucleus. The chromatin is finely granular but not scanty, and there is a nucleolus in each nucleus. These cells appear to have the capacity to form acinar and islet cells; both types have been observed arising from this common origin.

Endocrine Portion: In the pancreas of the snake almost all the islet tissue is situated in the splenic end of the pancreas.

There are, however, numerous small islets scattered throughout the body of the pancreas. This condition is similar to that observed by Thomas (1942) in his series of snakes. The islets in the splenic end appear to have an irregular outline and are of large dimensions, one of the larger islets measuring 1,057 × 500 microns. The islets in the body of the gland are smaller, usually comprising only a few cells. Connective tissue may enclose the islets, and capillaries follow the course of the trabeculæ which tend to divide the tissue into cords of cells. However, there may be no demarcation between acinar and islet tissue in which case one of the following conditions may obtain:—

(a) Small islet masses of four or five cells may be completely surrounded by acini, or form part of an acinus. In these cases the islet cells are always orientated towards a blood vessel.

(b) A few acinar cells, or two or three acini may be observed lying within an islet.

As stated above, primitive duct cells or the cells of the tubules appear to play an important role in the formation of new islets. These cells are fairly numerous in the islets where they are arranged around a small lumen, together with a few alpha or beta cells. On the other hand, isolated tubules are found scattered between acini. In this position too, their function is demonstrated by the fact that young islet cells can be seen forming among the duct cells.

Four types of cells have been observed in the islets; these are distinguished as alpha, beta, C and D cells. There is in addition, a cell containing basophilic substance.

Alpha Cells (Figs. 3a-3f): These are numerous, constituting 40-45 per cent. of the cells in an islet. They contain bright red-staining, refractile granules (Mallory Azan stain), which are of a coarser nature than the beta or D granules. The cytoplasm is faintly basophilic, and the oval vesicular nuclei each have a nucleolus. A secretory cycle has been established for the alpha cell, and various stages are depicted in Fig. 3.

Fig. 3a is an agranular or C cell. In the anabolic cell (Fig. 3b) the granules make their appearance in the centre of the cell near the nucleus. As anabolism proceeds the number of granules increases, and the nucleus moves from the centre to the anti-haemal pole of the cell, (Fig. 3c.), which at this stage is usually columnar in shape, and the granules so numerous that little cytoplasm can be observed. In the storage phase (Fig. 3d), the nucleus is obscured by the granules which present an almost homogeneous appearance due to the fact that they are so closely packed. The cells degranulate from the haemal pole, and the degranulating cells have the characteristic flame shape seen in Fig. 3e. The nucleus in this phase may be slightly more chromatic than in the earlier stages of the cycle. Fig. 3f is a later stage in the secretory cycle.

BETA CELLS (Figs. 4a-4d): There are approximately as many beta as alpha cells, although there may be individual variations in the islets. The granules in these cells are orange or yellow staining with azocarmine, finer and less refractile than the alpha granules.

Fig. 4a depicts an agranular cell. In the beta cell the first granules to appear are peri-nuclear (Fig. 4b). In the fully granulated cell (Fig. 4c), the granules, although numerous, are not as closely packed as in the alpha cell at this stage. The nucleus is more chromatic and may be irregular with an indented nuclear membrane. In contradistinction to the alpha cell the shape of the degranulating cell does not apparently change, although it is difficult to distinguish the cell membrane. In Fig. 4d, which is a degranulating cell, the position of the membrane has been indicated by a broken line.

C CELLS (Figs. 3a and 4a): The cells are usually found in groups, in a rosette arrangement. They are oval or cuboidal, and the cytoplasm is clear and faintly basophilic. The nucleus is oval, or spherical as in the duct cells, and lies slightly eccentrically. Although vesicular, the nucleus appears more chromatic than in the alpha or beta cells.

These cells are almost identical in structure with the cells of the tubules described above. A complete secretory cycle for the C cells cannot be established, and they are regarded as the agranular stage in the cycle of the alpha or beta cells.

D CELLS: These cells are the least numerous, and are not seen in every islet. Occasionally a group of two or three cells is observed, but usually single cells lie scattered between the other islet cells. They are oval or wedge-shaped and contain numerous fine basophilic granules. The nucleus is oval, and fairly chromatic. A secretory cyclo for these cells could not be established.

CELLS CONTAINING BASOPHILIC MATERIAL (Figs. 5a-5d): In Figs. 5a-5d are represented cells which are frequently seen in the islets of *Boodon lineatus*, but which I have not observed in human or guinea pig pancreas. The cells are not numerous, but are present in practically every islet. They may be the same size as an alpha cell or twice as large. Their shape is oval or spherical and they contain a deeply basophilic substance which is unlike cytoplasm in appearance. This substance varies in quantity in the cells in which are often found granules identical to alpha granules. The basophilic material has the structure of coarse irregular masses, and there is apparently a proportional relationship between the quantity of material and the alpha granules. Cytoplasm is not seen, neither is there a nucleus in every cell, but where there is a nucleus it lies against the cell membrane. It is oval and vesicular.

These cells are not recognised as any described cell type and it is impossible to establish for them a place in the normal secretory cycle of the other cells in the islet.

## DISCUSSION.

In general these observations correspond closely with those of Thomas (1942) on American snakes, but there are certain differences which must be briefly considered.

Pancreatic tissue is not incorporated in the splenic tissue in *Boodon lineatus*, but it has been observed in the splenic capsule. Further, not only is the extremity of the pancreas very intimately related to the spleen, but an accessory pancreas has been found at the cephalic pole of the spleen. How this relation between the two organs has come about cannot at present be decided. It may imply a more intimate developmental relationship in the snakes than in mammals, or may be merely a result of their close apposition.

Thomas (1942) states that the islets in the spleen are functional, but that for the acini to remain so, the cells must be connected with the main body of the pancreas The accessory tissue observed in *Boodon lineatus* has the appearance of being functional, and the cells all appear perfectly normal. It must be concluded that both the exocrine and endocrine tissue attached to the spleen is capable of normal function. Presumably, therefore, the exocrine tissue must have a duct system either independant of or connected with that of the rest of the pancreas, but this has not been seen.

The acinar cells in the American snakes are similar in structure to those described here. Thomas (1942), however, describes in the pancreas of some diamond-back rattlers and cotton-mouth mocassin snakes, a series of degenerative changes in the acinar cells. In one form of degeneration the zymogen granules are retained and become very enlarged and highly refractile. There follows a change in staining reaction from red to orange and the granules may be extruded in this form, or may decrease in size and increase in number until the cells are filled with fine granules which stain a dull pink-red shade. This type of degeneration, Thomas thought "reminiscent of the so-called 'Mankowski' cell." In *Boodon lineatus*, however, no Mankowski cells were observed.

There is little doubt as to the existence of a secretory cycle in the acinar cells. Although the methods used in this study did not provide satisfactory details of the changes in the cytoplasmic inclusions necessary for the establishment of a cycle, nevertheless certain criteria in this respect were fulfilled One of these is the increase in number of the zymogen granules and the coincident shifting of the nucleus from the centre towards the base of the cell. Another is the enlargement of the granules during the late katabolic stage of the cycle, possibly due to the coalescence of several smaller granules prior to extrusion from the cell. According to Thomas (1942) the enlargement of the granules is one of the early stages in the degenerative process. However, in Boodon, as there were no changes in staining

reaction, nor decrease in size of the granules, this enlargement is regarded as a normal phenomenon.

Comparing the acinar cells of the snake with those of a mammal such as the guinea pig, certain structural differences are noted. In the guinea pig the zymogen granules are never as large as those seen in the snake, in any phase of the secretory cycle. The nucleus in the snake is spherical, and most of the chromatin surrounds the large, central nucleolus; in the guinea pig the shape is oval and the chromatin is attached to the nuclear membrane and to a lesser degree to the eccentrically placed nucleoli of which there may be two. The small compact Golgi apparatus of the snake differs from the large loose reticulum usual in the guinea pig in which the Golgi threads are much coarser. The large mitochondria typical of the guinea pig are replaced by very fine, minute rods and filaments hardly visible even under oil immersion. In addition the cells of the snake possess the orange-staining substance described above. Thomas (1942) saw a nebenkern or " paranucleus " lying in the basal chromidial substance of some American snakes. This is possibly the same substance as that described here, which corresponds in structure with the nebenkern of Opie (Cytology of the Pancreas).

A matter of prime importance in the snake pancreas is the relationship between the ducts and acinar and islet tissue. The fact that young exocrine and endocrine cells can be observed lying in the duct epithelium and next to one another in the same duct is clearly indicative that from the ducts new tissue is formed, and as Thomas points out, " each appears to be only a modification of the duct cells with which they are so intimately associated." It is possible that these are not true secretory ducts, but part of a system of tubules described by Bensley (1911) in the guinea pig pancreas, the main function of the tubules being the formation of new tissue. Another significant factor in this regard is the form and arrangement of the islets in relation to the tubules and acini. According to Bensley (1914), ". . . with a few exceptions, all the islets of the pancreas are connected at some place with the duct system. In only a few instances, however, does the lumen of the tubule penetrate the mass of the islet, and even then it is everywhere separated from the islet cells by the duct cells." A condition similar to this has been observed in one of the specimens where the duct was seen to be surrounded by islet tissue. The presence or absence of connective tissue surrounding the islets can also be explained on Bensley's thesis. " If the islet has originated from the main duct or one of its branches or from the web of ductules referred to above, its position is primarily interlobular, and it will have a more or less well-defined capsule. If on the other hand, it has originated from several intralobular ductules, it will be in continuity with acini on all surfaces." This condition has also been observed, and the small intralobular ductules are often seen lying at the periphery of the islets.

The stages in the secretory cycle of the alpha cells are comparable in most cases with those described by Lombard (1940) in the islets of the human (Bantu) pancreas. Gillman (1939) provided certain criteria for identification and acceptance of a new cell type. These state that the cell must have a phylogenetic history, it must be formed at a definite period in ontogeny, and all the morphological changes in the cell during the secretory cycle must be known. At one stage in the cycle the cell may have a completely different form from that at another stage. These conditions have been satisfied for the alpha cell.

In Boodon mention has been made of certain basophilic cells which have not been identified as a specific cell type. Gomori (1941), in his description of the cells in the human islets, observed transitions between alpha and D cells. He says, "Intermediate shades from ruby red to clear blue granules can be seen," implying a change in staining reactions of the granules. He believes that the D cells are probably aged alpha cells, and finds both in the same relationship to the acini and epithelium of the ducts. Thomas (1942), on the other hand, found cells similar in staining reactions to his D cells, but they contained varying numbers of orange coloured or beta granules. In *Boodon lineatus*, the condition is more like that described by Gomori (1941), but the masses of basophilic material are too coarse to be regarded as the fine basophilic granules seen in the D cells. The presence of alpha-like granules in the cells may indicate a transition to an aberrant form of alpha cell seen in snakes, but not in mammals, or may be a form of degeneration of the alpha cells. In the castration cells of the pituitary gland, certain morphological changes are noted, namely the enlargement in size of the cell, and of the Golgi area, and the formation of a vacuole which almost fills the cell. There may be some correlation between the cytological changes in the beta cell in the pituitary and those noted in the cell described here—a change in function causing a change in morphology. However, the exact nature of these basophilic cells is not fully understood.

The beta cells are apparently quite normal and similar in structure to the beta cells in the guinea pig or human pancreas. The C cells are regarded as the agranular stage in the secretory cycle of either alpha or beta cells, and they are almost identical in appearance with the undifferentiated duct cells or cells lining the tubular system described by Bensley (1911).

## SUMMARY.

1. In *Boodon lineatus* the pancreas is a small compact organ attached by a mesentery to the gut at the level of the pyloro-duodenal junction. Its tail lies in close proximity to the caudal end of the spleen. In one instance a small accessory pancreatic nodule was found at the cephalic end of the spleen, and in the

same specimen pancreatic tissue was identified embedded in the splenic capsule.

2. Zenker-formol has been found to be the most generally satisfactory fixative for the histological study of the snake pancreas.

3. The general histology of the snake pancreas is similar to that of the mammalian pancreas. It has been observed that the islet tissue is principally located in the splenic end of the organ.

4. Histologically and cytologically the pancreas of *Boodon lineatus* compares closely with those of American snakes.

5. Special attention is drawn to the presence in the pancreas of Boodon of a system of tubules, apparently distinct from the excretory ducts of the gland. These tubules are lined by undifferentiated duct epithelium, which appears to have the potentiality for giving rise equally to acinar and islet tissue.

6. The alpha, beta, C and D cells observed in the islets are similar to those found in the guinea pig pancreas. The basophilic islet cells have only been observed in the snake and are not regarded as a specific cell type.

I have to thank Professor R. A. Dart in whose department this work was carried out. It was done under the direction of Dr. Joseph Gillman to whom I am indebted for his invaluable advice and criticism. I also wish to thank Dr. L. H. Wells for his suggestions, Miss Sylvia Kisner for preparing the illustrations, Miss Nora Smith for assistance with the manuscript and Mr. Hall for supplying the snakes.

## BIBLIOGRAPHY.

(1) BENSLEY, R. R.: "Studies on the Pancreas of the Guinea Pig." *Am.J.Anat.*, **12**: 297-388 (1911).

(2) BENSLEY, R. R.: "Structure and Relationship of the Islets of Langerhans." *Harvey Lect.*, Ser. 10 (1914-15).

(3) GILLMAN, JOSEPH: "The Golgi apparatus in human (Bantu) tissues, its role in secretion and its relation to cellular organisation." Thesis., unpublished. p. 479 (1939).

(4) GOMORI, G.: "Observations with differential stains on Human Islets of Langerhans." *Am.J.Path.*, **17**: 395-406 (1941).

(5) LOMBARD, F. A. B.: "The Alpha Cells in the Human (Bantu) Islets of Langerhans." *This Journal*, **37**: 218-227 (1940).

(6) OPIE, E. L.: "Cytology of the Pancreas in '*Special Cytology*.'" Ed. E. V. Cowdry. V. I., pp. 373-405 (1932).

(7) THOMAS, T. B.: "The Pancreas of Snakes." *Anat.Rec.*, **82**: 327-339 (1942).

TABLE 1

| Specimen and Experiment | Fixative | FIXATION | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Fix. time | Shrinkage | Acini | Cytoplasm | Nuclei | G.A. | Islets |
| 1 (A) | 10cc. Z.F. + 1cc. aq. dest. | 5½ hours | Slight | Fair | Good | Good | — | Poor |
| 2 (B) | 10cc. Z.F. + 4cc saline | 7 ,, | Moderate | Fair | Poor | Poor | — | Very good |
| 3 (C) | 10cc. Z.F. + 4cc. saline | 8½ ,, | Slight | Good | Good | Good | — | Too few seen |
| 4 (D) | 10cc Z F. + 5cc. saline | 8 ,, | Slight | Good | Fair | Good | — | Good |
| 1 (E) | 10cc. Formalin + $Co(NO_3)_2$ + 1cc aq. dest. | 2½ hours | Marked | Poor | Poor | Poor | — | Not seen |
| 2 (F) | 10cc. Formalin + $Co(NO_3)_2$ + 4cc. saline | 2½ ,, | Marked | Poor | Very Poor | Poor | A few | Alpha grans. good |
| 3 (G) | 10cc. Formalin + $Co(NO_3)_2$ + 5cc. saline | 3 ,, | Moderate | Poor | Poor | Fair | A few | Not seen |
| 4 (H) | 10cc. Formalin + $Co(NO_3)_2$ + 5cc. saline | 2½ ,, | Slight | Fair | Fair | Fair | Many | Alpha grans good |
| 1 (J) | 10% Formalin | 23 hours | Marked | Poor | Poor | Poor | — | Not seen |
| 2 (K) | 10% Formol-saline | 24 ,, | Marked | Poor | Poor | Poor | — | Poor |
| 3 (L) | 10% Formol-saline | 24 ,, | Slight | Fair | Fair | Fair | — | Good |
| 4 (M) | 10% Formol-saline | 24 ,, | Marked | Fair in patches | Fair in patches | Fair | — | Alpha grans. good |

Zymogen granules are 'good' in all the above experiments. Z F. = Zenker formol. G A. = Golgi Apparatus.
In (B) Mitochondria are demonstrated in acini and ducts; in (K) and (M) in acinar cells.

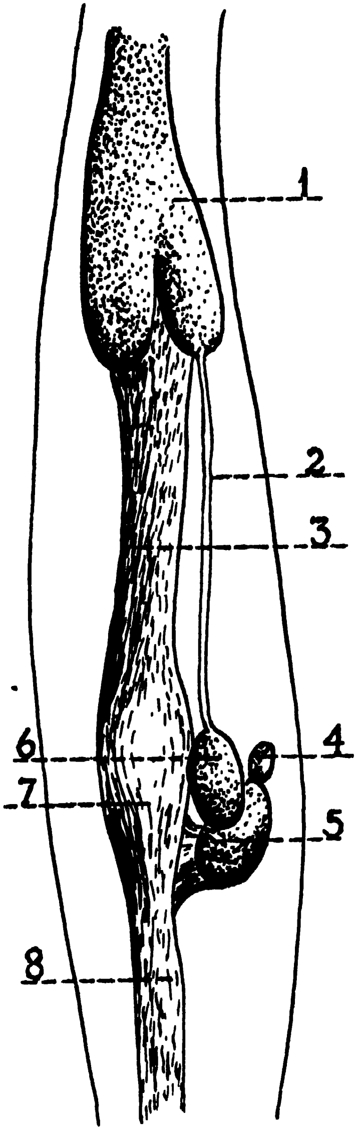
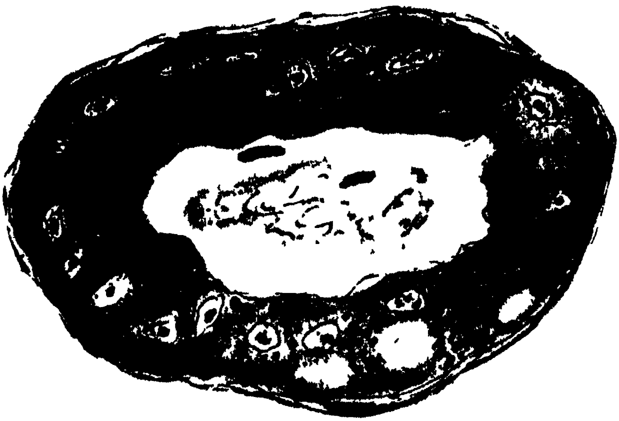
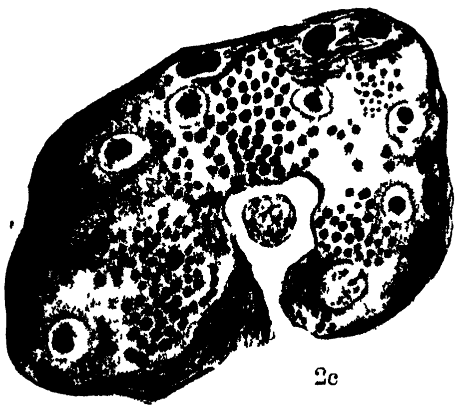



Fig. 1—Upper abdominal cavity, showing relation of pancreas to other organs: 1, Liver; 2, Bileduct; 3, Stomach; 4, Spleen; 5, Pancreas; 6, Gall Bladder; 7, Pyloro-duodenal Junction; 8, Duodenum.

2a

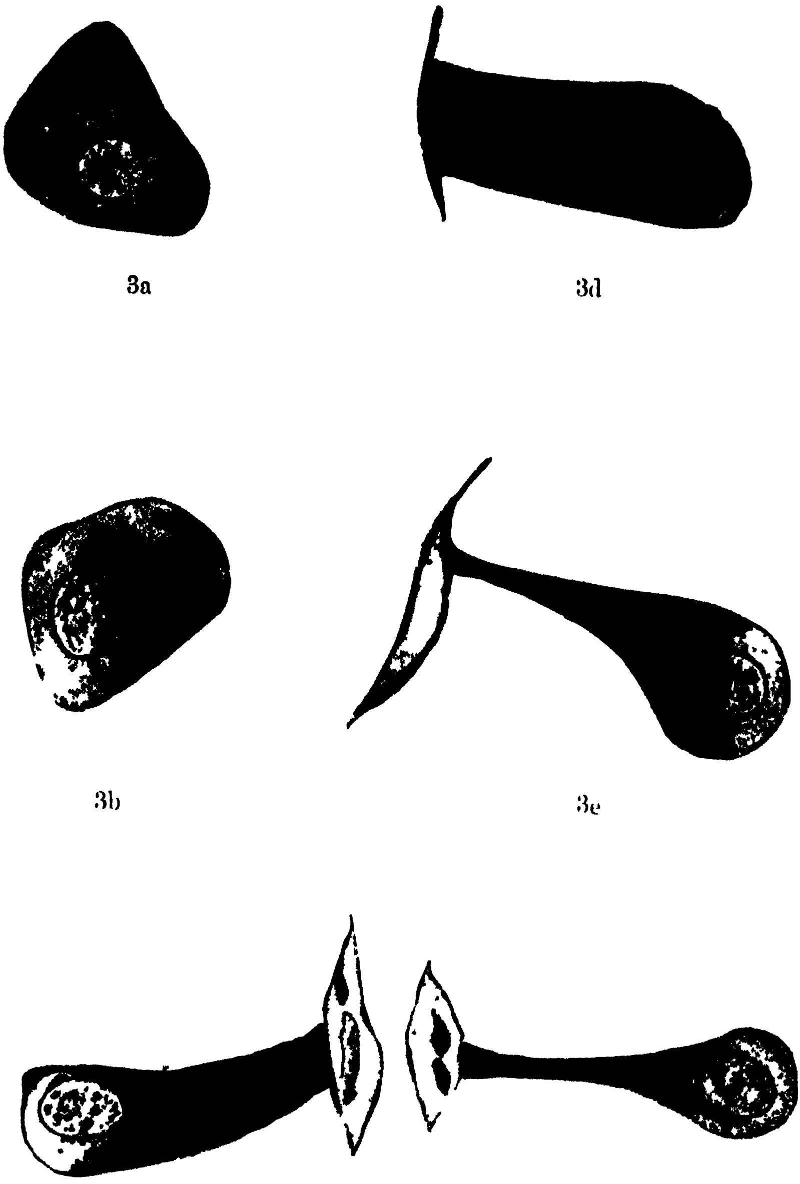


2b



2c

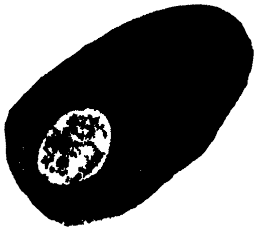
Figs. 2a and 2b—Zymogen cells forming in a duct.
Fig. 2c—Zymogen cells arranged in the form of an acinus. The nucleus of a centro-acinar cell can be seen in the lumen.




Figs. 3a to 3e—Stages in the secretory cycle of an alpha cell.

4a

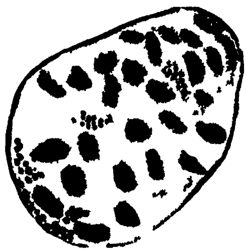
4c



4b

4d

Figs 4a to 4d—Stages in the secretory cycle of a beta cell



5a

5b

5d

Figs 5a to 5d—Cells containing basophilic material In Figs 5b, 5c, 5d can be seen alpha granules.

South African Journal of Science, *Vol. XL, pp. 240-247, November, 1943.*

# A REPORT ON A COLLECTION OF SKULLS FROM KRUIDFONTEIN, PRINCE ALBERT DISTRICT, C.P.

BY

A. I. I. Klopper,

*Department of Anatomy, University of the Witwatersrand, Johannesburg.*

*With 3 Text-Figures.*

*Read 29th June, 1943.*

This record concerns a collection of eleven skulls which were, with one exception, all exhumed from graves on the farms Groot Kruidfontein and Abraham's Kraal, in the immediate vicinity of Kruidfontein station, near Fraserburg Road in the Prince Albert district. The remaining skull (4190) comes from the farm Lammer Kraal some miles away; the reason for its inclusion in this series will become evident later.

These skulls were exhumed at various times by members of the staff of the South African Museum and form part of a collection at present on loan to the Witwatersrand University. Notes on some of these specimens in the Museum records indicate that they were buried under cairns, in either a sitting, or a horizontal flexed position. (This was confirmed by verbal information from Dr. S. H. Haughton who collected some of the specimens.)

Any determinations of sex are merely inferential as only the skulls are available. The remaining parts of the skeletons are in Geneva and no records of sex are to hand. Inferences as to sex, although by no means fundamental to the evidence presented, are, nevertheless useful in explaining the variations within a sub-group.

A metrical analysis of the skulls is presented in Table 1. The non-metrical features were analysed according to the scheme laid down by Galloway (1937).

As a result of these analyses these skulls divide themselves naturally into three groups.—

(a) Two skulls, 1885 and 3059, the latter being fragmentary closely comparable with Broom's Kalahari Bush material (1923);

(b) Five skulls (1462, 1887, 1888, 3457 and 4188), closely comparable with Drennan's Oakhurst material (1937);

(c) Four skulls (1886, 3057, 3058 and 4190), not immediately identifiable with any previously described type.

SUB-GROUP A.

Skull 1885 (Fig. 1) is the robust skull of a fully adult individual. The basioccipito-sphenoid suture is closed and the sagittal suture already shows signs of obliteration. When viewed from above this skull shows typically the features associated with Bushman crania. It is short with well-developed parietal bosses which make it comparatively wide across the parietal region. The frontal width, on the other hand, is relatively small so that the skull tapers anteriorly. In the inter-parietal region the sagittal suture shows slight grooving.

In frontal view the vertical forehead, with the abrupt turn of the frontal bones, is Bushmanoid in appearance. Certain of the features are, however, very strongly reminiscent of the Boskop skull. The supraciliary ridges are remarkably well developed and the glabella is considerably more prominent than is usual with the Bush type. This skull resembles Dreyer's Boskopoid Matjies River skulls in the possession of a metopic ridge. The nasal region is of characteristically Bush type, with a large interorbital breadth and small delicate nasal bones, so flat that they face completely anteriorly. Due to the over-hanging glabella, the upper nasal region has an actually indented appearance. The nasal aperture is trapezoidal and hardly extends up between the orbits at all. A Boskopoid feature is seen in the lower orbital margins which are broad and flat. The cheek bones turn back abruptly while the lower face shows subnasal and dental prognathism.

In keeping with the Bushmanoid appearance of the skull, the norma basalis shows a palate which is shallow and slopes anteriorly, with a horse-shoe shaped alveolar margin. The glenoid fossa shows a Boskopoid feature in the extension of the articular surface onto the tympanic plate. The small flat occipital condyles and the nearly circular foramen magnum are Bush features, but the relatively well-developed mastoids are more of Boskop than of Bush type.

The lateral aspect fits well Broom's description (1923) of pure Bush type. As he aptly puts it; "The whole parietal region is depressed as if a board had in infancy been tied against the posterior half of the parietals and pressed in the direction of the alveolar point." Other evidence of Bush blood may be seen in the relative shortness of the occiput, the curve of the superior temporal line and in the fact that the squamous temporal bone does not rise above pterion.

When one considers the measurements and indices, the evidence is overwhelming. The correspondence between the dimensions of this skull and those laid down for the Bush type by various authors, is remarkably close. Using Galloway's figures for the Bush skull (1937) as a standard, a brief comparison of the major dimensions will serve to point the close similarity. The cranial length is exactly the same, the cranial breadth and basi-bregmatic height differ from Galloway's

figures by only one millimetre. As a result there is naturally a close correspondence in the cephalic and altitudinal indices.

As regards the other indices, these all fall in the Bush category, e.g., the nasal index is platyrhine and the orbital index microseme. The cranial capacity of the skull is 1370cc. This is rather high for the Bush type and can be accounted for only on the assumption of some additional robust element such as Boskop.

This skull is predominantly of the Bush type, but with certain features which do not fall in with present day concepts of the typical Bush skull. In every case these aberrant features are characteristic of the original Boskop skull. In fact there is a striking similarity between this skull and Laing's (1924) Za3 and Za1. It is intermediate in character between these specimens, being less Boskopoid than Za3 and more so than Za1.

Skull 3059, is a fragmentary one in which the face, the greater part of the frontal bone and the right parietal bone are preserved. The skull is that of an adult. Although no third molars are present the roots of the second molars are well formed and here appears to be no alveolar space for the third molars. One may then presume that in this individual the third molars would probably never have appeared.

Too little of the calvaria remains to provide any sound diagnostic features, but from the slope of the bones one can surmise that the skull must have shown in some degree the Bush feature of narrow frontal and broad parietal regions. Also the top of the skull appears as flat as Bush crania usually are. The whole forehead is preserved and this appears to be of good Bush type. As is usual with this race the frontal bossing is infantile, the forehead low and vertical, turning back abruptly into the vault. Above the slight glabella are faint supraciliary eminences, while the lateral supraorbital triangles show only slight excavation. The orbits are high and quadrilateral with thin margins while the interorbital depth is, however, small.

The nasal bones are missing, but from the form and position of the nasal process of the maxillary bone, one can deduce that they must have been small and flat as in all Bush skulls. Further evidence of Bush blood may be seen in the trapezoidal nasal aperture, the shallow subnasal region and the short and shallow pallate. Only two indices can be calculated, the nasal and the orbital. These agree with the Bush type in being platyrhine and microseme.

The fragmentary nature of this skull does not permit of any conclusive diagnosis, but on the basis of the characters enumerated, it appears to be essentially of a Bush type.

## Sub-Group B.

These skulls form a very homogeneous collection. One character in particular is illustrative of their close affinity; in

Skull 1462, there is present a well-developed " os japonicum " and in three of the others an incipient suture indicates a tendency to the formation of this bone. Indeed, one is tempted to regard these skulls as having come from individuals of the same family group.

The skulls of sub-group b, form such a close series that one can make legitimate deductions as to sex. Skulls 3457 and 1888, appear to be those of adolescent females, in each of which only one of the last molars have erupted. Of the remainder, Skulls 1462 and 4188 (Fig. 2), are those of more mature males in which the dentition is complete and the basioccipto-sphenoidal suture is closed. Skull 1887, is that of a juvenile of 6-8 years, judging from the state of the dentition.

These skulls are distinguished from the Bush type represented in sub-group a, in the following respects:

(1) Their length is consistently greater.

(2) They are less broad than the skulls of the preceding group, and consequently they are all dolichocephalic.

(3) Their height is greater, as a result of which they are acrocephalic.

(4) The upper face is longer and the nasal bones distinctively elongated.

In all these features the skulls of sub-group b, show a striking correspondence with the crania from the Oakhurst Cave described by Drennan (1937). Of these Oakhurst people Drennan writes: " These cave-dwellers are taller, more robust than the ordinary Bushman. In this respect they resemble a type to which the name Hottentot has frequently been applied.

The main conclusion to which I have been led by a study of these Oakhurst cave-dwellers is that it is to the Boskop type in our own South African caves, and not to relatively modern migrations and hybridisations that we must look for the immediate ancestry of the Hottentot."

Drennan's view of the physical identity of the Hottentot differs from that of Broom (1923) who regarded as typically Hottentot, a series of very elongated skulls from Upington. Skulls similar to those described by Broom have been recovered from the same general area along the lower course of the Orange River by Dreyer and Meiring (1937), who also regard them as typically Hottentot. On the other hand, Keen (1942) has described from this same Orange River area, skulls which approach more closely to the Oakhurst crania.

In view of the divergent opinions of such authorities as Drennan, Broom and Dreyer on the identity of the fundamental Hottentot physical type, it seems preferable to attach local, rather than ethnological labels to the various morphological racial types which have been identified. For this reason I would

suggest that the type represented by our sub-group b, should be referred to as the " Oakhurst type."

### SUB-GROUP C.

Two of these Skulls (4190 and 1886, Fig. 3) are those of adults. They are both damaged, but fortunately the nature of the damage is complementary. Their homogeneity can be sufficiently established from the overlapping features so that one has no hesitation in including 4190 in this group, although it comes from Lammer Kraal, some miles on the other side of Fraserburg Road. Skulls 3057 and 3058, are those of juveniles. From the nature of the dentition, 3058 appears to have been 8-9 years old and 3057, six months to a year older.

The skulls of this group differ from those of the preceding groups in the following respects:

(1) They are strikingly broad-headed, so much so that one is on first examination not aware that they are by no means also short-headed. The adults do not show to any extent the Bush character of frontal narrowing. They have, in fact, broad frontal bones.

(2) Their nasal bones are longer and more massive than those of the Bush type (sub-group a), but less elongated than those of the Oakhurst type (sub-group b).

(3) The alveolar margin is U-shaped and the mastoid process well-developed—too much so for a pure Bush type.

(4) There is no protrusion of the occipital condyles and the whole area round the foramen magnum appears depressed.

(5) When seen from the side, these skulls are orthognathous, but may show slight subnasal prognathism.

These skulls represent a type which is not immediately identifiable with any previously described, except in so far as they are comparable with the skulls called " Strandlooper " by Shrubsall (1907).

Morphologically this type is explicable as the product of hybridisation of the Bush type with a larger and more robust type, such as that represented by the Boskop skull, i.e., a development of the process already recognised in Skull 1885, of sub-group a. We have also seen that Drennan relates the Oakhurst type represented by our sub-group b, to the Boskop type. Dreyer, Meiring and Hoffman (1938) have drawn attention to the genetic possibility of types as diverse as these arising by the hybridisation of two racial stocks, one large-headed (our Boskop type), the other small-headed (the fundamental Bush type).

### DISCUSSION.

The three morphological cranial types represented in this collection have been interpreted as diverse products of hybridi-

sation between two parent stocks, Bushman and Boskop. Two of these three types conform to well-recognised morphological entities, the Kalahari Bush type of Broom, and the "Oakhurst" type of Drennan. The third has not yet been identified with any particular type yet described.

Although these remains are from a comparatively small area, we have no way of determining how long a period they cover, or whether that period falls wholly within prehistoric or partly within historic times. This last possibility is important, since in historic times a foreign population might have been brought to this area from a considerable distance. If it could be shown, for instance, that the most purely Bush type represented an aboriginal and one or both of the others an immigrant population, we should be in a position to attach far more definite significance to these variations in type.

On behalf of the Department of Anatomy, I wish to thank the South African Museum for the loan of this valuable collection. My thanks are also due to Prof. R. A. Dart, in whose department this investigation was conducted; to Prof. M. R. Drennan for his constructive criticism and the facilities for examining the Oakhurst material, and to Dr. L. H. Wells, whose advice has been of great help throughout.

## REFERENCES.

BROOM, R.: "A contribution to the craniology of the yellow-skinned races of South Africa." *J.R.Anthr.Inst.*, **53**: 132-149 (1923).

DRENNAN, M. R.: "Archaeology of the Oakhurst Shelter, George. Part III. The Cave-Dwellers." *Trans.Roy.Soc.S.Afr.*, **25**: 259-280 (1938).

DREYER, T. F. and MEIRING, A. J. D.: "A preliminary report on an expedition to collect old Hottentot skulls." *Sool.Nav.Nas.Mus.*, Bloemfontein, **1**: 80-88 (1937).

DREYER, T. F., MEIRING, A. J. D. and HOFFMAN, A. C.: "A comparison of the Boskop with other abnormal skull-forms from South Africa." *Zeits.Rassen.*, **7**: 289-296 (1938).

GALLOWAY, A.: "The skeletal remains of Mapungubwe" in *Mapungubwe: Ancient Bantu Civilization on the Limpopo.* ed. L. Fouche, pp. 127-174 (1937).

KEEN, J. A.: "Report on two Korana skeletons from Burial Sites near Upington." This *Journal*, **39**: 247-255 (1942).

LAING, G. D.: "A preliminary report on some Strandloper skulls found at Zitzikama." This *Journal*, **21**: 528-541 (1924).

SHRUBSALL, F. C.: "Notes on some Bushmen Crania and Bones from the South African Museum." *Ann.S.Afr.Mus.*, **5**: 227-270 (1907).

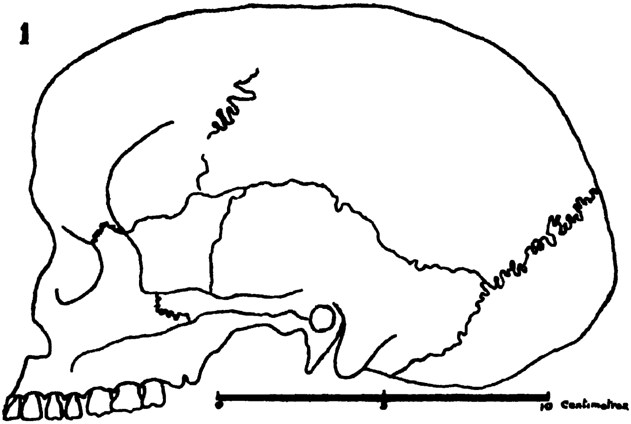
## CRANIAL MEASUREMENTS.

| Measurements | 1888 | 1887 | 4188 | 1885 | 1886 | 3457 | 4190 | 1462 | 3057 | 3058 | 3059 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cranial L. - | 18·0 | 17·2 | 18·5 | 17·7 | 18·0 | 17·7 | 18·0 | 17·7 | 16·5 | 17·9 | — |
| Cranial B. - | 13·2 | 12·3 | 13·4 | 13·0 | 14·3 | 12·3 | 14·8 | 13·0 | 13·7 | — | — |
| Basio-Breg. H. - | 12·2 | 11·6 | 12·9 | 12·1 | — | 12·6 | 11·8 | 12·5 | — | 11·2 | — |
| Aur. H. - | 10·9 | — | 10·9 | 10·2 | — | 10·8 | 11·2 | 10·5 | — | 9·6 | — |
| Leass. Fr. B. - | 9·8 | 9·3 | 9·4 | 9·6 | 10·1 | 10·2 | 9·8 | 10·5 | — | 9·6 | — |
| Upper Fac. H. - | 6·3 | 5·0 | 7·1 | 5·6 | 6·1 | 5·7 | — | 6·7 | 5·2 | 5·0 | 5·7 |
| Ex. Biorb. B. - | 10·5 | 9·4 | 10·2 | 10·6 | 10·9 | 10·8 | 10·6 | 11·0 | 8·8 | 9·3 | 10·6 |
| Bizyg. B. - | 12·7 | 10·3 | 12·4 | — | — | 12·2 | 12·0 | — | — | — | — |
| Orb. B. - | 3·9 | 3·7 | 3·9 | 3·8 | 3·9 | 3·8 | 3·8 | 3·3 | 3·4 | 3·0 | 3·8 |
| Orb. H. - | 3·4 | 2·9 | 3·5 | 2·9 | 3·3 | 3·3 | 3·3 | 3·1 | 3·0 | 3·4 | 3·5 |
| Inter. Orb. D. - | 2·2 | 2·2 | 2·9 | 2·6 | 2·5 | 2·6 | — | — | 2·0 | 2·5 | 2·1 |
| Nasal. H. - | 2·8 | 2·6 | 2·8 | 2·5 | 2·5 | 2·6 | — | — | 2·1 | 2·2 | 2·3 |
| Max. Alv. B. - | 5·8 | 5·3 | 6·1 | 5·7 | 6·0 | 6·0 | — | — | 5·2 | 5·6 | 5·8 |
| Max. Alv. L. - | 4·6 | 3·8 | 5·5 | 5·0 | 4·5 | 4·5 | — | 5·3 | 4·0 | 4·3 | — |
| Pal. B. - | 4·0 | 3·2 | 4·0 | 3·9 | 4·0 | 4·0 | — | — | 3·2 | 3·1 | 3·8 |
| Pal. L. - | — | 3·6 | 4·8 | 3·8 | 4·1 | 4·3 | — | — | — | 3·5 | — |
| Bican. B. - | 3·7 | 3·4 | 3·8 | 3·8 | 3·4 | 3·6 | — | 4·0 | 3·3 | 3·6 | 3·8 |
| For. Mag. B. - | 3·3 | 2·8 | 2·7 | 3·4 | 2·9 | 3·0 | 3·2 | 2·9 | — | 2·9 | — |
| For. Mag. L. - | 4·1 | 3·9 | 3·5 | 3·8 | 3·7 | 3·5 | — | 3·6 | — | 3·7 | — |
| Cr. Capacity - | 1370 | 1139 | 1360 | 1370 | — | 1205 | 1213 | 1330 | | | |

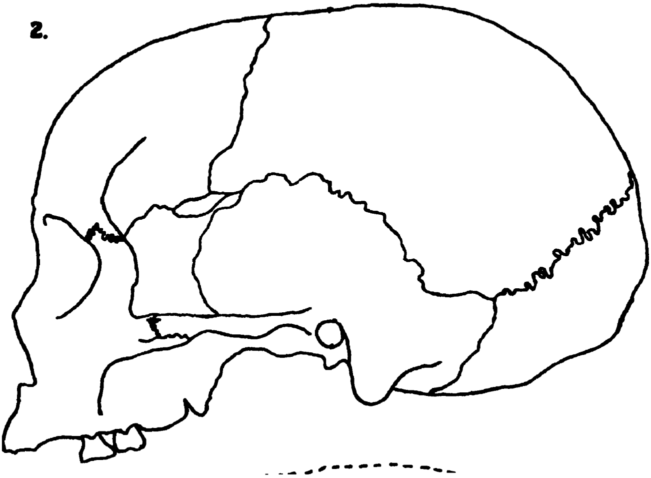
## INDICES.

| Index | 4188 | 3457 | 1462 | 1887 | 1888 | 3059 | 1886 | 4190 | 1885 | 3057 | 3058 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cephalic. I. - | 73·22 | 69·49 | 73·43 | 71·50 | 73·30 | — | 79·44 | 82·22 | 73·43 | 83·04 | — |
| Height. I. - | 70·49 | 71·18 | 70·62 | 67·44 | 67·77 | — | — | 70·62 | 68·40 | — | 62·56 |
| Ht. Breadth I. - | 96·26 | 102·44 | 96·15 | 94·31 | 92·42 | — | — | 96·15 | — | — | — |
| Up. Fac. I. - | 56·45 | 45·08 | — | 49·52 | 50·39 | — | — | — | — | — | — |
| Subgnathic. I. - | 70·70 | 58·51 | 67·00 | 56·67 | 60·08 | — | — | — | — | — | — |
| Orbital. I. - | 89·74 | 86·84 | 93·93 | 78·38 | 87·17 | 92·11 | 84·61 | 88·84 | 74·99 | — | 88·23 |
| Nasal. I. - | 58·33 | 65·00 | — | 70·27 | 58·33 | 53·48 | 55·56 | — | 60·97 | 52·50 | 59·45 |
| For. Mag. I. - | 77·14 | 85·71 | 80·55 | 71·79 | 80·48 | — | 78·37 | — | 89·47 | — | 78·37 |
| Inter. Orb. I. - | 28·43 | 27·77 | 27·27 | 23·40 | 20·45 | 90·81 | 22·93 | 21·69 | 24·52 | 22·72 | 27·06 |
| Max. Alb. I. - | 110·89 | 133·33 | — | 139·41 | 126·09 | — | 133·33 | — | 140·00 | — | |
| Bican. I. - | 62·29 | 56·67 | — | 64·15 | 63·79 | — | 56·67 | — | 66·60 | 63·00 | |

1




2.



South African Journal of Science, *Vol. XL, pp. 248-253, November, 1943.*

# OUR NATIONAL PARKS—PAST AND FUTURE

BY

Dr. R. Bigalke,
*Director of the National Zoological Gardens, Pretoria.*

*Read 28th June, 1943.*

Game reserves have been in existence in South Africa for many years, but the National Parks Act was not promulgated until the year 1926, and hence the Union's system of national parks only came into existence after that date.

As the oldest of our national parks, the Kruger National Park, has now been established for some sixteen years, the development of our national park system can profitably be reviewed and future trends discussed.

At present the Union's national park system consists of the following five parks:—

The Kruger National Park, established on the 15th September, 1926.

The Kalahari Gemsbuck National Park, established on the 3rd July, 1931.

The Addo Elephant National Park, established on the 3rd July, 1931.

The Bredasdorp Bontbok National Park, established on the 3rd July, 1931.

The Mountain Zebra National Park, established on the 2nd July, 1937.

When the National Parks Board of Trustees took over the Sabi and the Shingwedzi Game Reserve from the Transvaal Province, it was faced with the immediate task of making the new national park accessible to the citizens of the Union. This meant that the Board had to provide amenities so that people could visit the park and enjoy what it offers. In this respect the Board has rendered very valuable services under difficult circumstances, for not even the most sanguine protagonist of the national park idea could have anticipated the popularity of the Kruger Park. On account of this park's amazing popularity, almost from its inception, the Board's resources were taxed to the utmost to provide the necessary accommodation for the ever-growing stream of visitors. The work entailed the building of rest-camps, huts and stores in different parts of the huge area, the provision of water and sanitation, and the building of causeways and suitable roads. The Board's achievements in these respects have been very impressive, and it cannot be too highly complimented on what it has done with scanty means. But this does not imply that there is no room for further

improvements. More simple comforts, especially with regard to lighting and storage for luggage and foodstuffs in most of the rest-huts, remain to be provided.

Some people think that the provision of simple comforts in the rest-camps will " civilise " the Kruger Park too much. Every biologist and every lover of nature will agree that the animal and plant life of the park must for all time be left as undisturbed as possible, so that the inter-relations between fauna and flora may proceed in accordance with the natural laws. Problems may, of course, arise from time to time necessitating intervention, but steps should only be taken after a careful scientific study has shown what is to be done. The slogan in all our national parks should always be " as little human interference as possible." It cannot, however, be seriously maintained that the provision of simple comforts for visitors will effect the status of the flora and the fauna of the Kruger Park in any way.

Although five national parks are under its jurisdiction, the National Parks Board has concentrated its energies on the Kruger National Park, and the criticism has at times been made that little has been done to develop the other parks so as to bring them within reach of the public.

In the case of the Kalahari Gemsbuck Park and the Mountain Zebra Park, the Board's policy is undoubtedly based on the fact that little can be done until such time as good roads have been made, so that these parks may be accessible to tourists. At present both these parks are still closed to the public.

Since 1938 the Bontbok National Park has been open to visitors from December to April every year, and as a road has been made, visitors are able to see the flourishing remnants of the bontbok. That the public is making use of the facilities is shown by the fact that in 1939 some seventy cars were admitted to the park.

The Addo Elephant National Park is about thirty-five miles north of Port Elizabeth, and its principal attraction is the herd of about twenty-five Addo Elephants that it contains. In the year 1938 about 130 cars were admitted to the park, and in the year 1939 the number was about ninety-seven.

The rapid progress that has been made with our system of national parks and the very favourable reaction of the people of South Africa calls for a review of the position.

### Constitution of the National Parks Board.

The National Parks Act makes provision for the appointment of ten members by the Governor-General. Every Administrator of a Province in which any national park is situated and the Wild Life Protection Society, are entitled to nominate one member. That the right of the Wild Life Protection Society is entrenched in the Act is both just and wise, for there is

certainly no other public body that has done more to bring our national parks into existence than that Society. Its efforts in this respect go back to the year 1912, when the Society urged the Government to nationalise the Sabi and the Shingwedzi Game Reserve (Stevenson—Hamilton, 1937: 133).

According to the Act the Kruger National Park was established "for the propagation, protection and preservation therein of wild animal life, wild vegetation and objects of zoological, ethnological, historical or other scientific interest, for the benefit, advantage and enjoyment of the inhabitants of the Union." The National Parks Board of Trustees has now been in existence for more than sixteen years, but in spite of the Act's very clear statement of objects, no zoologist or botanist has ever served on the Board. This is an amazing state of affairs that requires prompt rectification. The omission is so glaring as to make further comment superfluous.

To make the necessary provision, the Board's personnel should be increased to twelve members, and it should be clearly stipulated that of this number at least one should be a zoologist and one a botanist. It may be desirable, also, to have a veterinary surgeon on the Board.

### Proposed Reorganisation.

The National Parks Board of Trustees does not seem to have the power to make recommendations for the creation of new national parks. This is an important matter that requires early attention. In fact, the Union Government should extend the Board's powers to such a degree that the Board may become the Government's adviser on all matters pertaining to the Union's national park system.

An alternative method would be to create a state department after the fashion of the National Park Service of the United States of America, but it is doubtful whether such a department would enjoy sufficient freedom of action in the Union.

To-day the White Rhinoceros occurs in the Union only in Zululand. The preservation of this animal has long ago ceased to be a provincial matter, and hence the time is more than ripe for transferring the Zululand Reserves and the Natal provincial parks generally from provincial to national control.

Another important matter is the creation of a national park in the Orange Free State for the highveld fauna. This province is the only one in which there is no national park at present, but the Somerville Reserve could be raised to that status. If this were done, it would make provision for the almost extinct Black Wildebeest.

More efficient administration and uniformity of policy and achievement will result if the administration of the national parks were reorganised. The writer is of the opinion that the time has come for the creation of a central office under a Director of National Parks with the necessary staff stationed

at Pretoria. Where it is warranted by the circumstances, each national park will have the following resident staff:— superintendent or warden, clerical staff, rangers, guide-lecturers, tradesmen, handymen, camp attendants, native police, natives, etc. At present the complete staff here visualised would only be found in the Kruger National Park, as the other parks have not yet been developed sufficiently. In any case, some are so small that they will never require the same staff as the large parks.

The trading-rights of the Kruger Park are at present in the hands of private individuals or companies that have competed for them by means of tenders. Owing to the many thousands of visitors in normal times, the concessionaires have found this a very profitable investment. As the Park's revenue from this source has amounted to but a fraction of the profits actually made by the different store-keepers within the Park, the Board has missed a valuable source of revenue over a period of years—revenue which would have been of great help to maintain and improve the Park. As soon as normal conditions have returned, the Government should take immediate steps to provide the National Parks Board with funds to take over all stores, so that all profits from the sale of goods and petrol and oil may in future accrue to the Park. In the past the prices charged in the stores have in some cases been much too high. If the Board assumed control, such matters could be adjusted. This step would, however, entail the appointment of a business manager, who would have the necessary staff in each store in the Park. An efficient manager should be able to provide the Board with considerable revenue from the stores every year.

The reorganisation here proposed can be tabulated as follows:—

BOARD OF TRUSTEES (TWELVE MEMBERS).

Director of National Parks.

Business Manager (Kruger National Park).

Kruger National Park.

All other National Parks and Staffs.

Store Attendants.

Clerical Staff.

Native Staff.

Superintendent or warden, clerical staff, guide-lecturers, rangers, tradesmen, handymen, camp attendants, native police, natives, etc. (The full complement would at present be found only in the Kruger Park.)

### Scientific and Educational Activities

Now that the task of providing accommodation and other facilities for tourists has been largely completed, there are two important matters which require the Board's attention at an early date, and these are the scientific and educational activities

of the national parks, especially of the Kruger Park. There is scope for much expansion in these activities.

One of the first scientific tasks to be carried out in the Kruger Park will be to make detailed surveys of the fauna and flora and their distribution in the Park. Thanks to the good work done by Col. Stevenson-Hamilton, much is already known about the mammalian and the bird fauna of the Kruger Park, but detailed surveys are necessary of both these and other groups. Similar surveys are also necessary of the flora and of the geology (Bigalke, 1939).

For the scientist the Kruger Park is above all a fruitful field for the study of the ecology of animals. Problems which should meet with early attention are the inter-relations between carnivorous and herbivorous animals, the study of animal populations and their cyclic fluctuations, the diseases and epidemics of the wild animals, the relationship of supplies of food and water to the animal populations and methods of improving the position where necessary, the effects of veld-burning, and the seasonal migrations of the ungulates. The latter is especially important, as it is desirable that the hoofed animals should be abundant in the Kruger Park during the winter months when the Park is open to the public. The influence of veld-burning on the ungulate populations and methods of checking or influencing their migrations (e.g., the efficacy of salt and bone-meal licks etc.) require thorough investigation. Much could perhaps be achieved by deepening natural water-holes and vleis where they occur, so that their water supplies may last as long as possible during the dry season.

The scientific study of the fauna and flora of the Kruger Park will furnish a continuous supply of reliable information upon which the educational activities of the Park can be based.

If tourists are to derive the maximum benefit and pleasure from the utilisation of our national parks, it is necessary that everyone must be given the opportunity of understanding and appreciating the principal features of the parks. At present the Board of Trustees has no definite educational policy for any of its parks, and the time is certainly ripe for inaugurating such a policy in the Kruger Park.

It is true that the Kruger Park enjoys an excellent press service. In normal times the larger newspapers in Johannesburg have regularly featured supplements when the tourist season has opened. But more than this is required.

Col. J. Stevenson-Hamilton has published two books, one of which (Stevenson-Hamilton, 1929) deals with the Kruger Park's wild life, its flora and its people, and the other gives an account of the origin of the Park (Stevenson-Hamilton, 1937). The writer is responsible for a guide to some of the commoner animals (Bigalke, 1939), and Mr. Herbert Lang has produced

an album of big game (Lang, no date). More low-priced guide-books are required dealing with the zoological, botanical, geological and historical features of the Park.

An educational policy for the Kruger Park will hardly be able to ignore what is being done in other parts of the world, particularly in the United States of America, which are the home of the national parks idea. The National Park Service of the United States avails itself of concise and well-illustrated guide-books dealing with the fauna, the flora and other features of the parks, of museums, lectures, camp-fire talks, special exhibits, library facilities and abundant literature on all major features of the respective parks. Field trips under the guidance of ranger-naturalists are popular features of the American parks. All of these methods cannot be applied to the Kruger Park, but many can be adapted to our conditions. The matter calls for investigation by the National Parks Board.

In this connection it is significant that an Advisory Board on National Parks, Historic Sites, etc., has been established in the United States to advise the National Park Service on many problems that require attention, and to elicit the maximum value of the national parks, especially in the educational field. This Board consists of eminent scientists and educationalists who serve in an honorary capacity, and whose work is entirely of an advisory nature on many matters—even on general policies, programmes of research, education and recreation—relating to the national parks of the United States. A proposal to establish a similar advisory committee for the Union's National Parks Board was recently made by the Wild Life Protection Society, but was not favourably received by the Board.

## REFERENCES.


(1) Bigalke, R.: National Parks and their Functions, with Special Reference to South Africa. S.A. Biol. Pamphlet, No. 10 (1939).

(2) Bigalke, R.: Animals and Zoos to-day. London: Cassell & Co. (1939).

(3) Bigalke, R.: A Guide to Some Common Animals of the Kruger National Park. Pretoria: J. L. van Schaik, Ltd. (1939).

(4) Cameron, J.: The National Park Service. New York: D. Appleton & Co. (1932).

(5) Lang, H.: South Africa's Big Game and other Animals. Cape Town.

(6) Stevenson-Hamilton, J.: The Low-veld: its Wild Life and its People. 1st Edn., London: Cassell & Co. (1929).

(7) Stevenson-Hamilton, J.: South African Eden. From Sabi Game Reserve to Kruger National Park. London: Cassell & Co. (1937).

(8) Stevenson-Hamilton, J.: "The Health of Wild Animals." *Jl.S.A. Vet.M.A.* **10**: 56 (1939).

(9) Stevenson-Hamilton, J. "Wild Life Ecology." Johannesburg: Assn. Scient. and Tech. Societies of S. Africa, 5th Lecture (1941).

(10) U.S. Dept. of Interior: National Park Service Administrative Manual. Washington (1941).

South African Journal of Science, *Vol. XL, pp. 254-257, November, 1943.*

# CRANIAL AND DENTAL CHARACTERS OF THE RECENT SOUTH AFRICAN EQUIDAE.

BY

H. B. S. Cooke,

*Department of Geology, University of the Witwatersrand.*

*With 1 Text-figure.*

*Read 28th June, 1943.*

A good deal of discussion and dissension has occurred in zoological circles regarding the specific distinction of the various striped horses which occur in Central and Southern Africa. The various species and sub-species of the so-called "zebrine" group have for the most part been recognised by variations in markings and colouring (e.g., Sclater, 1900). These criteria are manifestly of no value to the palaeontologist whose material is invariably skeletal. In order to provide a basis for the consideration of extinct types, the writer has accordingly carried out an extensive examination of the skulls and teeth of the living forms. As a result of this work it is possible to distinguish on cranial and dental characters three undoubted species, *Equus zebra*, the living mountain zebra, *Equus quagga*, the recently extinct true quagga and *Equus burchellii*, the living bonte-quagga or Burchell's zebra.

In the descriptions which follow, the nomenclature of the important elements of equine molar teeth follows the usage of Osborn (1907) with some minor amendments. The two enamel islands in the upper cheek teeth have long been known as the pre- and postfossettes, but the partial islands or inlets in the lower teeth have until recently received no name. Stirton (1941) has recently suggested the terms " metaflexid " for the anterior and " entoflexid " for the posterior partial islands of the lower teeth, and these terms are adopted here. In the upper teeth, the posterior groove which lies between the hypocone and hypostyle has been called by Stirton the " hypoconal groove " and the groove anterior to the protocone he terms the " preprotoconal grove." The present writer suggests " hypoglyph " and " protoglyph " to replace these rather clumsy terms.

A large number of skulls of the living zebra and bontequagga have been examined in the past few years, and it has also proved possible to study rare specimens of the recently extinct true quagga. Skeletal material of this extinct species is very

difficult to come by. There is a cast of the skull of a young individual in the Transvaal Museum, but hitherto, no actual specimens have been known. Dr. Broom has given the writer a rubbing made from the teeth of a specimen at one time in the collections of the Royal College of Surgeons.* and Sir Richard Owen figured a dentition in a little known paper (1869). From these data it has been possible to identify one skull in the Kingwilliamstown Museum and several in the McGregor Museum, Kimberley, as belonging to the true quagga. All these specimens were found on the farm Koffiefontein in the Kimberley district which lies within the known range of the quagga.

In the skulls of the three species, the zebra has a diastema between the third incisor and second premolar considerably exceeding the length of the premolar series; the quagga has a diastema generally less than the premolar length and the bontequagga or Burchell's zebra is intermediate between the two, the distance thus approximating to, or slightly exceeding the premolar length. In the mandible all these relations are similar, but the diastema is reduced slightly. The upper vestigial first premolar is generally present in bontequagga though characteristically absent in the others. The breadth of the upper cheek teeth (measured across the enamel from mesostyle to protocone) varies in each of the three species from 21 to 26 mm. and to the best of the writer's belief does not range outside these limits. Those of the bontequagga have the halves of the ectoloph concave inwards and curving easily into the styles, though the mesostyle may overhang slightly. In the true quagga and in zebra the halves of the ectoloph are almost straight or even slightly convex and are generally marked off rather abruptly from the styles. In zebra the parastyle is not normally abruptly marked off from the anterior moiety of the ectoloph and the mesostyle not very strongly so, particularly in the true molars. In quagga, however, the parastyle and mesostyle tend to overhang the ectoloph, the mesostyle being particularly abruptly marked off and sometimes almost isolated. In the true molars these trends are not so strong, but are more marked than in the zebra, though there is often a great deal of similarity in the true molars of all three species. In the third molars the distinction between the three species is almost impossible. In the teeth of zebra the protocone is small and reduced anteriorly. In quagga the anterior development is greater, the protocone is slightly larger and characteristically bilobate in form. In bontequagga the protocone is much the same size, but is not usually markedly bilobate and is more elongate. The fossette folds are variable, but the pli-prefossette is usually very weak or absent in zebra and quagga, but typically distinct in bontequagga and often quite strongly developed. The pli-protoconule is normally strong in bontequagga, but small

*Now probably destroyed as a result of the "blitz" on London.

or even lacking in zebra and quagga. There are also a number of other minor distinguishing characters such as the size of the hypoglyph which is normally small in quagga, and in the form of the inner wall of the protoconule and the shape of hypocone, but the ones cited above are sufficient for the distinction of the three species.

Fig. 1 shows typical upper and lower fourth premolars of the three species.

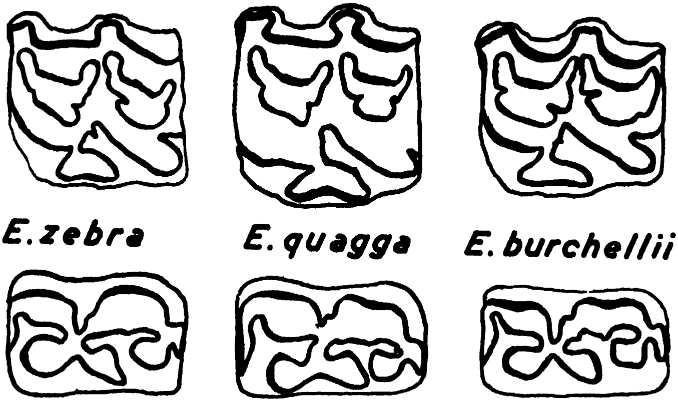



Fig. 1.

The lower cheek teeth range from 11 to 15 mm. in breadth across the enamel (protoconid or hypoconid to metastylid). The distinction of the three species is difficult owing to a wide range of variability, but in general, zebra is marked by the possesion of well rounded convex outer walls to the protoconid and hypoconid, an acutely pointed valley between metaconid and metastylid, and a pointed metastylid; bontequagga exhibits flattened or concave outer walls to the protoconid and hypoconid, a fairly acutely pointed valley between metaconid and metastylid and a less acute or even rounded metastylid; quagga shows a rounded or slightly flattened protoconid, a flattened hypoconid, a rounded valley between metaconid and metastylid and a bluntly pointed or rounded metastylid. There are few folds in the walls of the metaflexid or entoflexid in any of the species.

The characters of the incisor teeth, though subject to a rather large range of variation also show some notable features. The cup or " mark " is present in the three incisors of the upper jaw in all three species and in at least the first and second lower incisors of zebra and quagga. It is characteristically absent in all the lower incisor teeth of the bontequagga, a fact which has recently been discussed by van Hoepen (1940). There appears, however, to be a very large range of variability in the actual form of the incisors within each species.

From the point of view of classification, it would appear that the three species are quite distinct. The muzzle of the

true quagga is notably shorter than that of the zebra, though the cheek and incisor teeth have much in common. The bontequagga or Burchell's zebra, while showing skull characters intermediate between the other two forms, is sharply distinguished in dental character. There can thus be no doubt that the bontequagga is very distinct from the true zebra despite the many similarities of form and colouring which have caused much dispute amongst zoologists with respect to the relationship of the two forms. It differs to an equal degree from the true quagga, and can under no circumstance be regarded as a variety of this form. The specific designation *quagga* must, therefore, be restricted to the historically extinct true quagga, and the bontequagga or Burchell's zebra must receive the full specific name *burchellii* to which may be appended, if it is considered necessary, the varietal names *wahlbergi*, *transvaalensis* etc., though these varieties cannot be distinguished on skeletal or dental grounds as far as the present writer is aware.

## BIBLIOGRAPHY.

OSBORN, H. F.: *Evolution of Mammalian Molar Teeth.* New York: Macmillan (1907).

OSBORN, H. F.: "Equidae of the Oligocene, Miocene and Pliocene of North America; iconographic type revision." *Mem.Amer.Mus. Nat.Hist.*, n.s. **2**: 1-330 (1918).

OWEN, R.: "Description of the Cavern of Bruniquel and its organic contents. Part II. Equine remains." *Phil.Trans.Roy.Soc.*, London, **159**: 535-557 (1869).

SCLATER, W. L.: *The Mammals of South Africa.* Vol. I. London: R. H. Porter (1900).

STIRTON, R. A.: "Development of characters in horse teeth and the dental nomenclature." *J.Mammal.*, **22**: 434-447 (1941).

VAN HOEPEN, E. C. N.: "Oor die tande van de Equinae: I. Die snytande van die onderkaak." *Tydskrif vir Wetenskap en Kuns*, **1**: 101-114 (1940).

# A STUDY OF THE DENTITION OF *GAVIALIS GANGETICUS* LAURENTI AND *CROCODYLUS NILOTICUS* LAURENTI,

## With Special Reference to the Replacement of Teeth in Crocodiles.

BY

DR. F. GORDON CAWSTON.

*Read 28th June, 1943.*

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 258-270, November, 1943.*

# A FURTHER REPORT ON THE WONDERWERK CAVE, KURUMAN

SECTION I—ARCHAEOLOGY

BY

B. D. MALAN,
*Bureau of Archaeology, Johannesburg.*

SECTION II—FAUNA

BY

L. H. WELLS,
*Department of Anatomy, University of the Witwatersrand, Johannesburg.*

*With 1 Text Figure.*

*Read 28th June, 1943.*

## SECTION I

At the meeting of this Association in 1940 a preliminary account of the Wonderwerk Cave was given in which I briefly described the site, and Mr. H. B. S. Cooke described the faunal remains found in the course of excavations for fertilizer. In January, 1943, the present authors had an opportunity of continuing work in the cave for one week. This time was too short to do more than to prepare a plan of the cave and to conduct test excavations. Nevertheless, the results thus far obtained merit a further interim report at this stage.

Since my visit in 1940 the deposits in the rear portion of the cave have been entirely disturbed in the search for fertilizer, but they are untouched for a distance of about two hundred feet from the entrance. On measurement the cave was found to run into the mountain for some 460 feet from the entrance to the back wall. The width is 78 feet at the entrance, narrowing to about 35 feet for a distance of 150 feet from the entrance, and then widening to vary from 60 to 80 feet. The cave is apparently due to solution along a plane of weakness in the dolomite, but it comes to a dead end and no openings other than the front entrance were found.

Marks on the base of the east wall indicate that the present level of the surface of the deposit does not represent the maximum height to which the floor once rose. Near the entrance the floor at one time stood some two feet above its present level, while at 100 feet from the entrance only a few inches have been denuded. Use of the front portion of the cave in recent times

to shelter stock and as a wagon-house may have resulted in compression and possibly removal of the upper layers of the deposit, and it seems clear that at least some portion of the upper layers found its way down the slope in front of the cave. This slope is extremely rich in artifacts for a distance of about 50 yards from the cave mouth, though there is no true talus deposit. The paintings on the walls do not extend below what appears to have been the maximum level of the deposit. For purposes of the test excavations here described it was convenient to record depths from the present surface, bearing in mind that in the areas concerned only a few inches, if any, of the deposit have been removed.

Two test excavations were carried out, one at 200 feet from the entrance, and a second at 100 feet. The first was in complete, darkness and consisted in " squaring off " a face left by guano-diggers. The second approximates to the limit of paintings on the walls of the cave.

*Test Excavation No. 1.*—The excavation was abandoned at a depth of 4ft. 6ins., the deposit having proved sterile from 11 inches downwards. Throughout the depth excavated the deposit was clearly stratified and, in view of the results obtained in Test 2, the excavation should be continued when work in the cave is resumed.

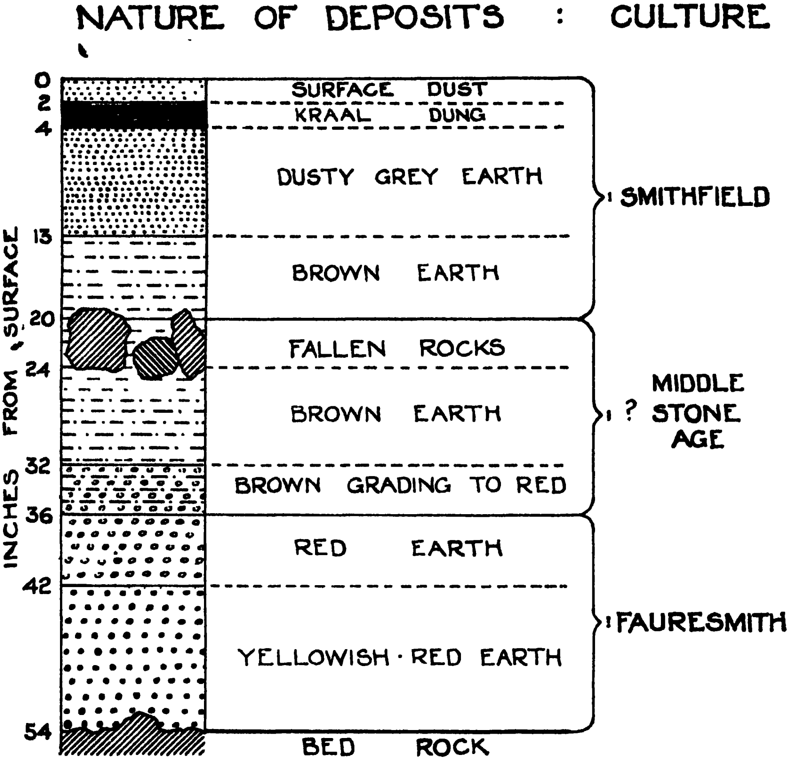
A reddish sandy layer between 8 and 11 inches below the surface, and a grey dusty layer between 3 and 8 inches contained an industry in grey chert. The material is uncharacteristic but shows a Levallois technique and includes several cores and a few crude scrapers. The workmanship is generally poor, but the unsatisfactory nature of the material used must be taken into account. The specimens are for the most part sharp and fresh, though a few are reworked on more weathered pieces, presumably brought from an unknown site outside the cave.

Above this, the topmost three inches of the deposit contained a few nondescript flakes and debitage which Test 2 leads us to assign to an early phase of the Later Stone Age.

*Test Excavation No. 2.*—Three square yards were marked off on the present surface and excavated to bedrock, but large rocks fallen from the roof reduced the area excavated below 23 inches to about two square yards. Bedrock was found to be very uneven, and was encountered at about 54 inches below the present surface.

The stratification encountered in this excavation is shown in the text figure. The red sandy earth between 36 and 42 inches and the yellowish-red layer from 42 inches to bedrock contained a number of finely made hand-axes of advanced Fauresmith type, all made of banded jasper, a very difficult material, the use of which was well mastered. In the small area excavated eleven complete specimens and fragments of a few others were recovered. These layers contained noticeably

fewer angular rock fragments than the over-lying deposits which were largely composed of rock fragments fallen from the roof of the cave.




The Fauresmith occupation is found from bedrock to 36 inches and was succeeded by an extremely rough, uncharacteristic industry which lies between (approximately) 20 and 36 inches from the present surface. This industry is rich in debitage, but very poor in recognisable cores or tools. The general technique can just be recognised as Levallois. The great majority of specimens show considerable weathering in varying degrees, some even being obviously water-worn. The chert used is extremely brittle, but this does not seem to account entirely for the very poor workmanship. The artifacts include some recognisable cores, and scrapers on cores and flakes, but the forms are inconsistent and erratic. It is a feature of the material in these layers that a very high proportion has been re-worked and shows fresh flake-scars intersecting and superimposed upon the older, more weathered facets. A large number of very small artifacts, many twice-worked with fresh later working, are of the order of size of microliths, but no recognisable microlithic forms are included.

Above this rather anomalous material occurred a very rich industry of Smithfield A culture. Since the cave is not far from the Koning Native Reserve which contains the type site of van Hoepen's (1926 and 1928) equivalent "Koningse Kultuur," this was not unexpected. The material now used was banded jasper for the larger tools, and chert for the smaller forms. The most numerous tool types are heavy fabricators, large core scrapers and those described by van Hoepen as disc-scrapers on slabs of the laminated jasper. One large and fine end-scraper of typical form was found. Concavo-convex forms would no doubt be difficult to achieve in this material, and none were found in the excavation. The artifacts in chert include cores, core scrapers and a few end-scrapers. Of the flakes of chert, very few show any signs of use. The artifacts in chert associated with the Smithfield A occupation differ markedly from those of the underlying anomalous industry in that they are nearly all perfectly sharp and fresh, and except for a few obviously derived pieces, none show any evidence of the Levallois technique. Apart from the stratigraphy which is in itself conclusive, we therefore have no hesitation in associating this material with the Smithfield industry of the site. The only other material in these levels is represented by a few quartz crystals, some of which have been used.

Particularly interesting associations with the Smithfield industry are considerable quantities of fragments of ostrich egg shell, fresh as well cooked or burnt. Three small fragments found between 4 and 13 inches from the surface show incised decorations: one has three (possibly four) parallel rows of lines each consisting of a fine zig-zag line resting on a straight line; on another three parallel lines cross-hatched form part of a larger design which is lost, while the design on the third cannot be deciphered. On two other fragments, found between 16 and 20 inches, evidence of incised decoration occurs; one has only a portion of a crudely incised straight line, while the other has a broad zig-zag line which may form part of a larger design. In the same level were also found the pointed fragment of a ground bone point, and the centre portion of another which had been burnt. In view of the abundance of ostrich egg shell fragments and the sophisticated designs on a few of them, we expected to find beads made of this material, but despite careful search none were discovered.

The material collected from the slope in front of the cave entrance requires to be mentioned. There is no talus deposit, presumably because the material found there represents a gradual "spilling" from the deposits in the cave, so that the fine earth was washed away, leaving the tools exposed on the surface. The artifacts collected in this area include many trimming stones and disc-scrapers, some crude scrapers on flakes, and a number of end-scrapers. The materials used are banded jasper and dark grey chert, and it is clear that the finds in front

of the cave do not differ materially from those of the Early Smithfield layers in Test Excavation No. 2.

Included in a box of faunal remains sent to the Bureau by Mrs. Bosman, wife of the owner of the farm, was an object of especial interest. It is a small semi-circular bow of bone, made from a long strip taken from a rib of some animal. It measures 17·3 inches along the arc, and 10 inches from tip to tip along the chord. The bone has been carefully rubbed to a lenticular cross-section, somewhat more convex on the outer surface. It is 0·4 inches wide at its widest part at the centre, and tapers to neatly rounded points at the tips. One end is perforated 0·4 inches from the tip; the perforation was done from the inner surface and is conical, the wider opening on the inner surface being $\frac{3}{16}$ths of an inch in diameter and the narrow opening $\frac{1}{8}$th of an inch. The other end was similarly perforated, but the tip has broken off at the perforation. Mrs. Bosman informs me that when found the object was complete with both tips, and that a small piece of fibre adhered to one of the perforations. but crumbled when touched.

It has not been possible to identify this object or to guess at its use. It could not have been used as a shooting bow, as its form is permanently in the fully bent position, and the bone is in any case fragile and not resilient. It is in a very fresh condition and cannot be of any very considerable age. We know of no references to such an object in the literature on the Bushman, and it is unknown to the authorities to whom we have been able to show it. Neither Professor P. R. Kirby, an authority on indigenous music, nor Professor L. F. Maingard, who has made a close study of the Bushman and related peoples, were able to recognise it. M. l' Abbé Breuil informs us that identical objects have been found associated with the Mid-Aurignacian culture in Europe, where they possibly formed part of a head-dress, but it would be most dangerous to apply this very remarkable analogy without supporting evidence.

*Discussion.*—This is the first time that the Fauresmith culture has been found in sealed deposits in a cave, and only the second recorded occurrence of Early Smithfield in a stratified cave deposit. The Fauresmith industry in the lower layers of the second excavation is a normal advanced expression of that culture but it is represented only by hand-axes. The entire absence of Levallois forms and characteristic debitage invariably associated with the Fauresmith wherever else it has been found cannot be explained until the excavations have been extended.

The very unsatisfactory Levallois material occupying the levels approximately between 18 and 38 inches appears to have undergone weathering outside the cave, and was probably derived from a site which must already have been old when the material was collected and brought into the cave. Although much of the material shows fresh re-working, this later working is too anomalous to be ascribed to a particular culture. The position

therefore is that we do not know by whom this material was introduced into the cave. Its stratigraphical position between advanced Fauresmith and Early Smithfield layers, and the fact that material with Levallois characteristics was chosen, suggests however that the people who introduced it belonged to the Middle Stone Age.

Early Smithfield tools have previously been described only from one cave site, at Umgazana on the Pondoland coast by Chubb, King and Mogg (1934). Only in that site have objects of bone previously been associated with the Early Smithfield. The absence of ostrich egg shell at Umgazana contrasts strikingly with its abundance in Wonderwerk Cave, though neither site has produced beads.

The Smithfield material represented in the upper levels of Wonderwerk Cave undoubtedly suffers from the difficulties inherent in the laminated nature of the banded jasper used. The workmanship is often poor, and the tools lack variety. The excellent hand-axes in banded jasper in the Fauresmith levels show, however, that this material when skilfully used could produce fine tools, and it may well be that the Smithfield industry in the cave must be regarded as somewhat decadent even after allowance is made for the unsuitability of the material.

## Section II.

The test excavations described by Mr. Malan in the preceding section yielded a number of determinable animal remains. In addition, Mrs. N. J. Bosman has presented to the Bureau of Archaeology an extensive collection of bones, horns and teeth recovered in the course of exploitation of the cave deposit for fertilizer, which can be compared with similar material previously described by Cooke (1940).

A. *Remains from the Test Excavations.*—The thin band of occupational dèbris in Test 1 yielded only a few indeterminable scraps of bone, including some charred fragments and one gnawed by rodents. In Test 2 animal remains were abundant in the more superficial (Late Stone Age) strata, and occasionally present in the deeper layers.

In the deposits containing Fauresmith hand-axes (below 36 inches) the few bones recovered are very severely leached; the only specimen even vaguely identifiable is a fragment from a molar of some large bovid. The bone fragments from the middle levels (20-36 inches), though appreciably altered, do not show the same degree of leaching. Here again only one possibly identifiable specimen is present, also a portion of a bovid molar, apparently either eland or kudu. These relics, while in themselves uninstructive, suggest that careful excavation of these deeper layers over a larger area might yield good faunal remains.

The Late Stone Age strata above 20 inches, on the other hand, produced a considerable number of bone and tooth fragments, considering the small volume of deposit examined.

Although more determinable specimens were recovered from the dusty grey earth above 18 inches than from the more coherent brown earth below, it has not been thought worth while to differentiate between these layers at present. Except for two obviously recent teeth of either sheep or goat found in the superficial kraal dèbris, all the remains are discoloured and somewhat leached. Among this material at least ten vertebrate forms are represented; all the identifiable species belong to the recent S. African fauna.

Class REPTILIA—Order CHELONIA.

A fragment of carapace and some limb bones indicate the presence of one or more species of tortoise.

Class AVES.

*Struthio* sp.—The ostrich is included in this list in view of the large number of fragments of egg-shell found throughout the Late Stone Age deposits.

Class MAMMALIA.

While the majority of the bone fragments are probably mammalian, only the teeth permit of more or less exact identification; no horns or horn-cores have been recovered.

Order PERISSODACTYLA—Family EQUIDAE.

Two upper and two lower equine cheek teeth in good condition have been obtained, besides fragments of several other teeth, some of which are charred. In size these teeth correspond with those of the recent S. African zebras; the larger extinct species (*E. capensis* and *E. kuhni*) identified by Cooke from this cave have not been found in our excavation.

Elsewhere in this volume Cooke has shown that the teeth of the true quagga (*E. quagga*) can be distinguished from those of the bontequagga (*E. burchellii*), and both these species from the mountain zebra (*E. zebra*). In this collection, as in that described by Cooke, both the true quagga and the bontequagga are represented.

*Equus quagga* Gmelin.—One complete upper tooth, a second molar, definitely belongs to the true quagga; the two lower teeth best preserved also agree best with this species.

*Equus burchellii* (Gray).—The other good upper tooth, a third or fourth premolar, belongs equally definitely to the bontequagga.

Order ARTIODACTYLA—Family SUIDAE.

*Phacochoerus africanus* (Gmelin.)—A complete third upper molar of a wart-hog already shows root formation on its anterior columns, although the hindmost columns have not yet come into wear. This feature assigns it definitely to the species *P. africanus* (Shaw 1939).

Family BOVIDAE.

*Taurotragus oryx* (Pallas).—The eland is definitely identified by an upper first molar.

cf. *Connochaetes* sp.—A very heavily worn lower molar appears to belong to a wildebeest. The posterior half of an erupting third lower molar may also belong to this genus, or possibly to the hartebeest (Alcelaphus).

cf. *Damaliscus* sp.—An erupting third lower molar most probably belongs to this genus, as may also a portion of an upper molar.

cf. *Sylvicapra grimmia* (Linn.).—A well worn upper molar most nearly resembles the Cape duiker.

cf. *Raphicerus campestris* (Thunb.).—A worn third upper premolar agrees best with that of the steenbok.

cf. *Tragelaphus* sp.—Two broken lower molars seem to correspond most nearly with this genus, but are somewhat above the average size for the bushbuck (*T. sylvaticus*).

B. *Other Faunal Remains*.—The material presented by Mrs. Bosman was obtained, like that previously described by Cooke, from the inner part of the cave where the deposit has been exploited for fertilizer. Most if not all of the specimens are reported to have come from a localised area of the deposit, but this cannot now be verified owing to the complete disturbance of all this portion of the cave.

These remains, which so far as they can be identified are all mammalian, include bone fragments, horns and horn-cores, and a large number of isolated teeth as well as portions of jaws, together with a few coprolites. In preservation these specimens agree exactly with Cooke's description of the earlier collection:

> "The bones are on the whole little impregnated but do show a certain amount of leaching and alteration. The teeth also are only mildly impregnated, although the larger equine molars appear more thoroughly petrified than the others."

Except for these last specimens the general condition of the bones and teeth is similar to that of the remains from the Late Stone Age layers of Test 2. One equine molar has been charred. Many fragments have been severely gnawed by rodents, probably porcupines.

The following identifications are based almost entirely upon horns and teeth; among the bones only two partial skulls can be named. Re-examination of the earlier collection in conjunction with this new material has led to the recognition in it of one or two forms additional to those listed by Cooke.

Order Primates—Family Cercopithecidae.

*Papio comatus* E. Geoff.—The baboon is represented by a partial cranium of an old male.

Order Carnivora—Family Hyaenidae.

cf. *Hyaena brunnea* Thunb.—Part of the maxilla of a hyaena, containing the third premolar and the anterior half of the fourth, agrees more closely with the brown than with the

spotted hyaena. M. l' Abbé H. Breuil has identified coprolites of the hyaena in this collection, from which it may be inferred that the cave was at some time inhabited by these animals.

Family MUSTELIDAE.

*Mellivora capensis* (Schreber). A skull, almost complete though lacking nearly all the teeth, can be identified as that of a ratel.

Order RODENTIA—Family HYSTRICIDAE.

*Hystrix africae-australis* Peters.—The collection includes a palate and two mandibular fragments of the porcupine.

Order PERISSODACTYLA—Family RHINOCEROTIDAE.

cf. *Ceratotherium simum* (Burchell).—Several pieces of rhinoceros horn, one of them a nearly complete posterior horn, have been found. These may well belong to the white rhinoceros which was definitely identified by Cooke.

Family EQUIDAE.

This collection includes more than a hundred isolated equine cheek teeth, besides several maxillary and mandibular fragments, three premaxillae and a mandibular symphysis. As in the earlier collection, a small number of these teeth are distinguished from those of the recent S. African zebras by their greater size, while the great majority correspond in this respect with the modern forms. On the criteria established by Cooke, more than half of these smaller teeth can be definitely assigned either to the true quagga or to the bontequagga. The unidentifiable balance, consisting of milk molars and of unworn, heavily worn or badly broken permanent teeth, with a mandibular symphysis and two premaxillae, doubtless also belong to one or other of these two species.

*Equus burchellii* (Gray).—The bontequagga appears to be the less abundant of the two forms; only some ten upper and half a dozen lower cheek teeth can be definitely assigned to it. One of these teeth, a second upper molar, is unusually small, the transverse diameter of its crown being only 20mm.

*Equus quagga* Gmelin.—More than twenty upper teeth, a dozen isolated lower teeth and part of a mandible can be assigned to the true quagga. The relative frequency of this species and the preceding one in this collection is very much the same as was determined by Cooke.

*Equus* cf. *kuhni* Broom.—At least five upper teeth in this collection, though generally resembling those of *E. quagga*, exceed what Cooke regards as the maximum dimensions for this species, the transverse diameters of their crowns ranging between 27 and 30mm. These teeth correspond very closely in size and enamel characters with the two specimens which Cooke referred to *E. kuhni*, and may also be assigned provisionally to this species. As Cooke has pointed out, a number of lower teeth which are of rather large size for *E. quagga*, though in other

respects corresponding with it, may also belong to *E. kuhni* whose lower teeth are otherwise unknown.

Dr. L. S. B. Leakey in correspondence with Mr. Cooke and with the writer, has suggested that *E. kuhni* may be a S. African representative of the N.E. African species *E. grevyi* Oustalet. A cast of the dentition of the latter species, which Dr. Leakey has been so kind as to send us, shows a definite similarity between the two, but in the present state of our knowledge of *E. kuhni* they cannot be regarded as identical. It is however evident that in dental characters *E. grevyi*, like *E. kuhni*, approaches more nearly to the true quagga than to the bonte-quagga.

*Equus capensis* Broom.—Three lower premolars in varying states of wear are much larger than any others in the collection, their crowns measuring 19-20mm. across. Like the similar teeth described by Cooke, these agree very closely with Haughton's (1932) neotype of *E. capensis*. With them may be associated four upper teeth whose crowns exceed 30mm. in transverse diameter. Two of these, a right third premolar and a right third molar, are in a very advanced stage of wear; the former is possibly the companion to a left third premolar figured by Cooke. The other two, which are much less worn, and from their state of preservation may belong to the same individual as a broken left fourth premolar discussed by Cooke, are a badly battered left second molar and the posterior half of a left third premolar. In its crown pattern this last specimen agrees almost exactly with the corresponding portion of the type of *E. cawoodi* Broom, and thus provides further support for Cooke's view that *E. cawoodi* is within the range of variation of *E. capensis*.

Two other fragments of upper teeth, one of them charred, also appear large enough for *E. capensis*. A premaxilla with both first and second incisor teeth, which is very much larger than those assigned to the recent forms, possibly belongs to this species.

Order Artiodactyla—Family Suidae.

*Phacochoerus* cf. *africanus* (Gmelin).—Two fragments of canine teeth and a partially erupted third upper molar of a wart-hog are not specifically identifiable, but are tentatively assigned to *P. africanus* which was identified from our test excavation. Cooke tentatively identified a partially erupted third molar as *P. aethiopicus* (Pallas), but with the rider that it could not "be distinguished with any certainty from *P. africanus*."

Family Bovidae.

*Syncerus caffer* (Sparrman).—The Cape buffalo is represented by a fragment from the base of a horn and possibly also by a broken lower molar tooth.

cf. *Peloroceras helmei* (Lyle).—Cooke described teeth from this site resembling in form those of the hartebeest but considerably larger, and assigned them to this very large extinct

hartebeest-like antelope, first described by Lyle from Florisbad (Dreyer and Lyle 1931). Similar teeth among the new material comprise a series of three heavily worn lower molars in a fragment of a mandible, portions of three less worn lower molars, and five upper molars more or less complete and varying in degree of wear.

*Alcelaphus caama* (Cuvier).—Several horns and cores, a mandibular fragment, an isolated third lower molar, two third upper molars, and probably also three other upper molars in a very early stage of wear, all belong to the true hartebeest.

*Connochaetes* cf. *taurinus* (Burchell).—A large portion of a wildebeest horn agrees best with that of the blue wildebeest; a broken third upper molar is probably also to be assigned to this animal.

*Damaliscus* sp.—Two broken molars, an upper and a lower, may be referred to this genus, although the species is not determinable. Cooke tentatively referred similar teeth to the bontebok (*D. pygargus*), rather than to the blesbok (*D. albifrons*) which is the species found in this area in modern times.

*Antidorcas marsupialis* (Zimmermann).—Several springbok horns are included in this collection, and an upper molar tooth seems also to belong to this species.

*Taurotragus oryx* (Pallas)—In addition to horns and cores, a maxillary fragment, two mandibular fragments and five isolated teeth can all be assigned to the eland.

*Oryx gazella* (Linn.).—The gemsbok is identified by a large portion of a horn; a third upper and a third lower molar are probably also to be assigned to it. This animal was not identified by Cooke, but it is probable that at least one of the teeth referred by him to Hippotragus really belongs to the gemsbok.

cf. *Hippotragus equinus* (Desmarest).—One lower molar tooth agrees very closely with that of the roan antelope, and a large portion of a boldly curved horn-core may also belong to this type.

cf. *Kobus ellipsiprymnus* (Ogilby).—The terminal portion of a horn, although somewhat warped and corroded, seems to agree with that of the waterbuck.

cf. *Sylvicapra grimmia* (Linn.).—A nearly complete horn and a piece of frontal bone with a complete horn-core most probably belong to the Cape duiker.

cf. *Capra walie* Ruppell.—A large portion of a horn could not be recognised as belonging to any S. African antelope. This has been identified by Dr. R. Broom as that of an ibex, resembling the existing Abyssinian species. With this specimen before us, a fragment of another ibex horn can be recognised in the first collection from the cave. This has been regarded as part of an aberrant horn of some local antelope, but the specimen more recently obtained is too nearly complete to be interpreted

in this way. These horns are somewhat leached and clearly are not absolutely recent.

The presence of remains of ibex in this cave is most puzzling. No such animal existed in S. Africa within recent times, nor does this part of the country appear at all a suitable habitat for it. Dr. Broom has therefore suggested that these remains were brought to the site by man, by whose agency they may well have been transported from N.E. Africa. Although this explanation presents difficulties, no better one has yet been proposed.

It is however curious to recall that in this very area Daniell in 1801 sketched his "Tackhaitse," which in its published guise presented so ibex-like an appearance that it was named by Schinz "*Capra aethiopica.*" This creature is now recognised (Sclater, 1900) as being in reality the roan antelope, a type probably represented in the Wonderwerk fauna. Nevertheless the coincidence appears worthy of remark.

*Discussion.*—In the first collection from Wonderwerk, Cooke identified fifteen mamalian types. All of these appear to be represented in the material more recently presented by Mrs. Bosman, although in some cases there is a doubt as to the specific identity. This new collection also includes a number of forms not previously recorded from this site: baboon, hyaena, ratel, gemsbok, probably Cape duiker, possibly waterbuck, and most remarkable of all, ibex. Of these types, however, the ibex is certainly and the gemsbok very probably represented in the earlier collection.

Of these twenty or more species whose remains have been found in the inner part of the cave, the baboon, hyaena, ratel and porcupine may be merely intruders. The numerous ungulates, however, must owe their presence to the activity either of Man or of predatory animals such as the hyaena.

In our test excavations, the Late Stone Age deposits have yielded two zebras, wart-hog, eland, and probably some other antelopes which are also included in the other collections from the cave. Besides these there are several types not otherwise represented: tortoise, ostrich, steenbok and possibly bushbuck. These, however, have been identified from specimens so small that they would almost certainly have escaped the notice of the guano-diggers, especially in the darkness of the inner part of the cave. Their absence from the other collections may therefore be of no significance.

Apart from the problem of the ibex, the most notable feature of the faunal assemblage from this cave is the presence of three species known in a fossil state, but not as members of the recent S. African fauna. These are the large horses, *E. capensis* and *E. kuhni*, and the giant hartebeest-like antelope identified with *Pelorocera*s *helmei*. All three are well represented in both collections from the inner part of the cave, though none of them was recovered from the test excavations. These species existed up to the Middle Stone Age, but are not known to have survived

into Late Stone Age times (Cooke, Malan and Wells, 1942). Their presence led Cooke to anticipate that the fauna from the inner part of the cave might date back in part to the Middle Stone Age. Direct confirmation of this supposition has not yet been obtained. Our knowledge of the presence of these extinct species in the cave, however, adds still greater importance to the possibility that further excavation will produce faunal remains from Middle Stone Age or even Fauresmith as well as Late Stone Age deposits.

Both the archaeological and the faunal remains so far obtained thus demonstrate the necessity for more extensive systematic excavation of the remaining portions of the cave deposit. Such an excavation will be undertaken by the Bureau of Archaeology in conjunction with the University of the Witwatersrand at the first available opportunity.

We wish to record our thanks to Mr. and Mrs. N. J. Bosman for their continued interest in the site and for their very kind hospitality during our visit, and to Professor C. van Riet Lowe and Professor R. A. Dart for their encouragement to undertake this investigation and report. In the interpretation of various finds we have profited by the advice of M. l'Abbé Breuil, of Professors C. J. van der Horst, L. F. Maingard and P. R. Kirby, of Dr R. Broom and of Mr. H. B. S. Cooke; in view of Mr. Cooke's association with previous work on this site we much regret that military duties prevented his accompanying us on our visit. We have also to thank the University of the Witwatersrand for a grant which enabled Dr. Wells to take part in the investigation.

REFERENCES.

Chubb, E. C., King, G. B. and Mogg, A. O. D.: "A New Variation of Smithfield Culture from a Cave on the Pondoland Coast." *Trans.Roy.Soc.S.Afr.*, **22**: Part IV, 245-268 (1934).

Cooke, H. B. S., Malan, B. D. and Wells, L. H.: "The associated Fauna and Culture of Vlakkraal Thermal Springs, O.F.S." *Trans.Roy.Soc.S.Afr.*, **29**: 203-233, illus. (1942)

Dreyer, T. F. and Lyle, A.: "New Fossil Mammals and Man from South Africa.." Grey Univ. Coll., Bloemfontein. 60 pp., illus. (1931).

Haughton, S. H.: "The Fossil Equidae of South Africa." *Ann.S.Afr. Mus.*, **28**: 402-427., illus. (1932).

Malan, B. D. and Cooke, H. B. S.: "A Preliminary Account of the Wonderwerk Cave, Kuruman District. Sect. I: Site and Archaeology. Sect. II: The Fossil Remains. *This Journal*, **37**: 300-312 (1941).

Sclater, W. L.: "The Mammals of South Africa. **1**: R. H. Porter (1900).

Shaw, J. C. M.: "Growth changes and variations in Wart-hog Third Molars and their Palaeontological Importance." *Trans.Roy.Soc. S.Afr.*, **27**: 51-94 illus. (1939).

Van Hoepen, E. C. N.: "Die Indeling en Relatiewe Ouderdom van die Suid-Afrikaanse Klipwerktuie." *This Journal*, **23**: 793-809 (1926).

Van Hoepen, E. C. N.: "Die Koningse Kultuur. I. Die Koningse Industrie." *Arg.Nav.Nas.Mus. Bftn.*, Deel 1, Stuk 1 (1928).

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 271-281, November, 1943.*

# THE RECOGNITION OF HUMAN MALNUTRITION

BY

PROF. J. F. BROCK AND DR. J. M. LATSKY.

*Read 29th June, 1943.*

## THE DETECTION OF MALNUTRITION

The following consideration of the criteria by which a state of malnutrition in school-going children can be detected is drawn from the experience of the Cape Nutrition Survey.

The Cape Nutrition Survey was one of several surveys designed to investigate more intensively the problems raised by the general survey of European school-children throughout the Union, which had previously been carried out by the Public Health Department. The methods and results of the preliminary survey have already been published. In brief, the work was carried out by School Medical Officers throughout the four Provinces of the Union, who examined, weighed, and measured school-children after having met to agree on the standards which were to be adopted. After examination each child was put in one of the four conventional groups of the Dunfermline scale: 1. General condition excellent. 2. General condition good. 3. General condition requiring supervision. 4. General condition requiring treatment. A total of 58,165 European boys were examined and classified in this way. Classes one and two were regarded as of satisfactory nutrition and classes three and four were regarded as malnourished. The percentage figures for the Union were: nutrition satisfactory 59·7 per cent.; malnourished 40·3 per cent.

The question immediately arose as to how much reliance could be placed upon these figures. Jones (1937) has drawn attention to the different standards of normality set by different examiners in classifying children according to the Dunfermline scale. Although probably all examiners would be agreed on the recognition of the differences between groups one and four, experience shows that there is difference of opinion as to where the borderline between groups two and three lies.

The Cape Nutrition Survey set out to study the reliability of the criteria by which malnutrition is detected and to study the methods by which the role of defective diet in the production of malnutrition can be assessed.

McCarrison (1937) has defined nutrition as " the sum of the acts or processes by which the structure and functions of

all organs and parts of the body are established and maintained. It is, in short, that function of the body by which health is maintained."

It is generally agreed that the factors underlying malnutrition include disease, both congenital and acquired, parasitic infestation, over-crowding, defective hygiene, insufficient sleep, and emotional and psychological maladjustment. All play a role in the production of malnutrition. On the other hand it is clear that nutrition cannot be satisfactory unless the diet is satisfactory.

Before considering malnutrition we must consider what is normal nutrition. In all discussions of this subject it is apparent that we are dealing with two standards—normal and optimum. These terms need to be more clearly defined. Optimum nutrition can be defined as a state of nutrition in which there is no further room for improvement in the individual's physical development, functional efficiency or resistance to disease or strain. Downward departures from this optimum may be due to defective diet or to disease, or to any one of the many factors which have been listed as influencing nutrition. In order to distinguish between optimum nutrition and optimum health one might define optimum nutrition as a state of nutrition in which physical development, functional efficiency and resistance to disease or strain cannot be improved by further additions to the diet. But this definition is unsatisfactory because it excludes the effects of "conditioned deficiency" states in which for example, gastro-intestinal disorder may "condition" a deficiency state even when an optimum diet is being consumed. It appears, therefore, that no clear distinction in definition can at present be drawn between optimum nutrition and optimum health.

The term normal nutrition as usually used, indicates something which is satisfactory, but not optimal. The fact that the first two groups in the Dunfermline scale are labelled excellent and normal, shows that normal is not the same as optimal.

To the nutritionist the most important aspect of the nutrition problem is the definition of satisfactory and optimum diets. Optimum diet can be defined as a diet, further additions to which cannot cause any further improvement in the individual's physical development, functional efficiency or resistance to disease or strain. Without an optimum diet no individual can have optimum nutrition. On the other hand many factors which have been referred to above can prevent normal nutrition or normal health from being achieved even on an optimum diet. Since many of these factors are still only partially under human control. it is axiomatic to the nutritionist that every individual should have an optimum diet.

There is probably no such thing as a normal diet, and normal nutrition as opposed to optimum nutrition can probably be achieved on what is usually referred to as a satisfactory diet. This can be defined as a diet which is adequate to prevent any deterioration in health and efficiency under average conditions of life, and yet carries some margin to make it adequate for at least some of the abnormal calls which the individual is likely to meet, such as infectious illness, or violent exercise.

Having defined normal, satisfactory and optimum standards in relation to nutrition and diet, the problem of malnutrition can now be considered.

While the nutritionist recognises the numerous factors which enter into the production of malnutrition his attitude is that diet is the one factor which can be adequately controlled. His problem, therefore, is to know how the role of a defective diet in the production of an observed state of malnutrition can be assessed and distinguished from all those other factors which are contributory. In other words, is it possible to decide by examining a group of children, what percentage of them are not receiving an adequate diet, and in respect of what dietary components their diet is inadequate. This is the problem which the Cape Nutrition Survey attempted to tackle. The methods of the study have been reported elsewhere (Brock and Latsky, 1942).

## Degrees of Malnutrition

Malnutrition can be roughly divided into three degrees of severity. The worst can be called starvation. In this degree the individual is obviously thin, under weight, and usually of inferior stamina. Starvation is essentially the result of deficiency of total calories in the diet. In the intermediate degree the individual is not necessarily thin, but on examination certain defined stigmata of vitamin or mineral deficiency can be detected. In the case of vitamins, these stigmata are most commonly seen in the skin and mucous membranes; many of them are well described in the Report of the Bantu Nutrition Survey and in a recent paper by Suzman. This degree of malnutrition is especially caused by deficiency of protective foods, and can occur even when the total calorie intake is normal.

In the mildest degree of malnutrition, often referred to as sub-nutrition, the stigmata of vitamin or mineral deficiency may be absent, height and weight may be average, and very often the effects of the deficient diet can be recognised only by biochemical tests. The essential criterion of this sub-nutrition is that the physical and mental efficiency, stamina and resistance to disease can be improved by the provision of more protective foods. (Brock, 1943.)

## Clinical Appraisal

The basic method of nutritional assessment is careful

clinical examination. In the first place the child is searched for evidence of congenital abnormalities, acquired disease or endocrine disorder. If any such evidence is found the child is classified as "diseased." An attempt is then made to classify the remainder into "Normal" and "Malnourished" groups by the following methods.

Firstly it is possible in a clinical examination to detect the stigmata of recognised deficiency disorders, e.g., the epiphyseal enlargement of rickets, the keratomalacia of Vitamin A deficiency, etc. Some of these stigmata are established beyond question and a child showing one of them would certainly be placed in group four of the Dunfermline scale.

Other stigmata may be recognisable, which are known to clear up on a good all-round diet although the precise deficiency which causes them has not yet been identified. Such are certain departures from normality in the skin and mucous membranes. Certain of these are in the process of being identified, e.g. disorder of the facial skin and buccal mucosa associated with deficiency of riboflavin, nicotinic acid, and perhaps other components of the Vitamin B complex. The finding of any of these stigmata would lead a competent examiner to place the child in group four. Very few such definite stigmata were found in the Cape Nutrition Survey, but many were found in the Bantu Nutrition Survey (Kark and Le Riche, 1943), and among the Bantu population of Johannesburg (Suzman, 1942). Such definite stigmata of precise nutritional deficiency raise the presumption of defective diet, but occasionally the deficiency state may be conditioned by disease or gastro-intestinal disorder in the presence of a satisfactory diet and even sometimes in the presence of an optimal diet.

Other alleged stigmata of precise nutritional deficiency depend upon examination of the eye with special instruments. Delay in readaptation of the retina to "dark vision" after exposure to bright light, as measured by the Birch-Hirschfeld biophotometer or other techniques can almost certainly be due to deficiency of Vitamin A. On the other hand a similar dysadaptation may be due to disease of the eye such as retinitis pigmentosa. If the dysadaptation can be cured by administration of Vitamin A then it is presumably due to deficiency of that vitamin. But this therapeutic test is not quite infallible because the complication of improvement from "learning" has not yet been completely assessed when the test is done repeatedly on the same child. Dysadaptation in a group of children as compared with a control group, and improvement in the mean adaptation performance of the test group after administration of Vitamin A, could be regarded as strong presumptive evidence of deficiency in the test group. But it is doubtful how far the results of this test can be relied upon in individual cases at present. (Hecht and Mandelbaum, 1939, Thomson et al., 1939.)

Alterations in corneal vascularisation and conjunctival structure as detected by the slit lamp have recently been claimed to be stigmata of deficiency of Vitamin A and of riboflavin, but it is not yet certain whether these stigmata can at present be distinguished from similar effects of exposure to wind, dust and bright light. Group tests of the remedial effects of either Vitamin A or riboflavin with adequate control groups may yield presumptive evidence of deficiency, but as in the case of visual dysadaptation it is uncertain whether these criteria can be relied upon in individual cases. (Kruse, 1941, Berliner, 1942, Sydenstrickerstal, 1940.)

Göthlin (1937) in Sweden has claimed that the capillary fragility test is a reliable index of Vitamin C deficiency, provided that other causes such as blood disorders and infectious fevers can be excluded. Work in South Africa and in other parts of the world have not confirmed Göthlin's claims. Fox and Dangerfield (1940) have shown that capillary fragility is usually normal in Bantu mine workers whose dietary intake of Vitamin C, and whose blood ascorbic acid show them to be on the border-line of scurvy. It has been our own experience that among the Bantu the capillary fragility is usually normal even in the existence of manifest scurvy. Baumann and Brock (1942), found no correlation between the petechial index and the results of an intravenous Vitamin C saturation test. The sensitivity of the capillary fragility test as an index of Vitamin C deficiency has not been confirmed even in white-skinned people in North America. (Crandon, Lund and Dill, 1940.)

Other stigmata may raise the presumption of nutritional deficiency but yet be too uncertain in their aetiology to be attributable to a precise dietary deficiency. Such are the slight roughening of the skin, especially of the extensor surfaces of the arms, which may or may not be a precursor of the follicular hyperkeratosis of Vitamin A deficiency (Pemberton, 1940). This sign was found in a considerable percentage of coloured children in the Cape Nutrition Survey. Where it was well-marked, the child was classified in group three even if nutrition was otherwise judged to be satisfactory. All degrees of the condition were, however, seen, which merged imperceptibly into a normal skin and in some cases it was not sufficiently definite to justify relegating the child to the third group if other criteria were satisfactory.

Other stigmata may be of such a nature that the medical examiner regards them as probably indicative of minor ill-health which is not directly or necessarily due to dietary deficiency. And yet he may know that the incidence of these stigmata is greater in the poorer than in the more well-to-do sections of the community. An example is the very high percentage of coloured and poor European children in the Cape Nutrition Survey, who showed very obviously enlarged cervical glands.

The incidence was so high that it was thought unlikely that they could be due to tuberculosis. They were spread so widely through the neck that it was thought unlikely that they could be due to tonsillar sepsis, or to infection of the scalp secondary to pediculi. It was difficult to know how much weight to attach to such a stigma. In the Cape Nutrition Survey many children showing it were put in group two.

In general, therefore, these latter stigmata are of limited value in deciding where the border-line lies between groups two and three of the Dunfermline scale. When they are well-marked they do indicate that the observed state of malnutrition is due to defective diet, provided that the gastro-intestinal tract is functioning normally. On the other hand the lesser grades do not provide evidence that malnutrition is due to defective diet. It might equally well be due to one of the other many factors which are known to underlie malnutrition.

It would appear, therefore, that clinical appraisal can often establish the existence of what was referred to earlier as the second or intermediate degree of malnutrition. It is, however, unreliable in detecting the third or mildest degree of malnutrition or in terms of the Dunfermline scale it is unreliable in distinguishing between the second and third groups.

## Somatometric Indices and Skeletal Maturation

Numerous indices have been constructed from measurements of height, weight, etc., and have been claimed to be of value in detecting minor degrees of malnutrition. Skeletal maturation as measured by radiographs of the carpal epiphyses has also been suggested for the assessment of nutritional status. This subject has been discussed in separate communications (Latsky, 1942, Latsky, Richardson and Brock, 1943). The following general conclusions can be drawn:

Although malnutrition may adversely affect the growth and maturation of bone and the growth of tissue mass, the indices constructed from these measurements are all powerfully influenced also by inherited growth patterns which presumably act through the endocrine glands. The result is that although it may be possible with future developments to detect significant differences between groups of malnourished and normal children, none of these indices can be relied upon to classify an individual child as malnourished or normal.

Wetzel (1941) has constructed a grid for physical development derived from height and weight. He claims that his seven channels represent a range of physique from the obese to the very slender type. Healthy developmental progress continues in an established channel as though this were a preferred path, presumably dependent upon inherited tendencies. Channel-wise progress indicates development with preservation of given

physique; cross-channel progress is accompanied by change in physique; when it is towards the right it usually indicates deterioration in nutrition and when towards the left improvement in nutrition. This grid is probably of no value in determining the nutritional status of a child when a single set of measurements are taken. But it may prove to be of the greatest value in following the nutritional progress of a child over a period of years. It may be necessary to establish a special grid for South African conditions, because it was found by Latsky, Richardson and Brock (1943) that normal Cape Coloured children were advanced by a mean figure of 0·52 years over Wetzel's scale constructed in U.S.A. In view of the absence of racial homogeneity it may, however, be necessary in South Africa to construct separate grids for the different races and it will be necessary to remember that acquired endocrine disturbances may very possibly result in cross-channel progress which will be indistinguishable from that due to nutritional change.

## Anaemia and Nutrition

In the absence of infective or other disease and of intestinal parasites and malaria, the finding of anaemia might be regarded as indicative of malnutrition. Severe anaemia probably only develops from dietary deficiency as distinct from disease and intestinal parasitism when the dietary deficiency is severe. An exception to this statement is the nutritional anaemia of infants which develops from iron deficiency in children born of iron-deficient mothers, when mixed feeding is introduced late. Mild degrees of iron-deficiency anaemia are commonly found in women existing on poor diets during the child bearing epoch of life, but are uncommon in adolescents. In the Cape Nutrition Survey it was found that blood loss from intestinal parasites was uncommon and it was concluded that low haemoglobin figures might be indicative of dietary deficiency. Unfortunately the lower level of normal haemoglobins has never been determined. The subject is to be fully discussed in another paper. The conclusions in brief are as follows. There was a significant difference between the normally nourished and malnourished children in the Cape Nutrition Survey, but the scatter diagrams showed so much overlap that only the lower levels of haemoglobin could be accepted as evidence of malnutrition. Iron-treated cases could not be accepted as indicating the lower levels of normality, since iron therapy has a stimulant action on haemopoiesis distinct from its action in correcting deficiency states. Haemoglobin figures below 11 grams per cent. are indicative of iron deficiency if disease and blood loss can be excluded. Haemoglobin figures between 11 and 13 grams per cent. indicate possible iron deficiency which can be regarded as probable if the mean corpuscular haemoglobin concentration is less than thirty-two.

## Biochemical Tests for Mineral and Vitamin Deficiency

From the foregoing discussion it seems likely that although there are certain clinical stigmata and measurements which detect malnutrition when it is present in gross form, most of them are unreliable for the detection of minor degrees of malnutrition, and furthermore, they fail to distinguish between the effects of disease and of dietary deficiency. It seems likely that precise criteria of minor deficiency of protective foods will only be derived from biochemical studies which indicate the quantity of each mineral and vitamin present in the body. These tests are concerned chiefly with certain minerals and vitamins the level of which in the tissues is believed to be reflected either by the level in the blood, or the excretion in the urine before and following test doses with the mineral or vitamin concerned. This line of investigation is of great value because it enables dietary malnutrition to be analysed into deficiency of precise dietary essentials, which can further be expressed in quantitative terms. A great deal has been written about these tests recently. Reference to some of them can be found in a book by Youmans (1941) and an editorial in the Lancet (1942).

Unfortunately most of these tests suffer from the same defect as the method of clinical assessment according to the Dunfermline scale: there is as yet no acceptable definition of the lower level of normality or of the border-line between normality and subnormality. This difficulty is best exemplified in the experience of the Cape Nutrition Survey with the Vitamin C saturation test. The significance of what is called Vitamin C subnutrition has been discussed at length by Fox (1940 and 1941) and by Brock (1942). The latter has pointed out that whereas levels of food or vitamin intake are usually divided into (a) the physiologically indispensable minimum, (b) the adequate and (c) the saturation or luxus consumption level, category (a) should be subdivided in the case of Vitamin C, into (i) the indispensable minimum for the prevention of recognisable scurvy and (ii) the indispensable minimum for the prevention of any deterioration of health from Vitamin C deficiency. Fox has shown that even the level for (i) is hardly known, whereas, the level for (ii) is still a subject of much speculation. A diagrammatic representation of these levels is given in Figure 1. The figures can only be approximate as will be explained, but the diagram illustrates the different levels of Vitamin C intake referred to above as a, i, a, ii, b, and c, and the concept of vitamin subnutrition represented by the range of intakes between a, i, and a, ii. In the case of the Vitamin C saturation test used by the Cape Nutrition Survey (Wright, Lilienfield and MacLenathen, 1937, Portnoy and Wilkinson, 1937) an excretion of 40 per cent. of the injected dose is usually regarded as the lower level of normality. On the other hand, Fox and Dangerfield (1940) found no evidence of incipient scurvy in the great majority of Bantu mine workers, on intakes associated with a saturation test result of certainly

less than 20 per cent. and Jokl and Suzman could find no evidence of deterioration in the physical efficiency of these men over long periods of time. The Cape Nutrition Survey found that although of 268 children submitted to this test, 154 or 57·5 per cent. excreted less than 40 per cent., only 25 or 9 per cent. excreted less than 36 per cent. It could hardly be claimed in the light of the work of Jokl and Suzman that the 129 children who excreted between 36 per cent. and 40 per cent. suffered in any way from their alleged deficiency of Vitamin C.

The same difficulty applies to determinations of the fasting level of ascorbic acid in the blood. Fox (1940) has tabulated the usually accepted views as follows:—

| | | |
|---|---|---|
| Figures below 0·1 mg. per cent. | = | very poor and usually associated with scurvy. |
| 0·1 to 0·4 mg. per cent. | = | poor. |
| 0·4 to 0·8 mg. per cent. | = | moderate. |
| 0·8 to 1·2 mg. per cent. | = | good. |
| 1·2 mg. per cent. and over | = | excellent. |

Even if it be accepted that the plasma level of ascorbic acid reflects the amount of ascorbic acid in the body the question still remains what is the level below which the individual health will necessarily suffer. In other words what is the lowest level which can be called adequate and what is the indispensable level to prevent any deterioration in health from Vitamin C deficiency, and what is the margin between these two levels? (See Fig. 1.) The adequate level must obviously be one which allows some margin for unusual calls on Vitamin C, such as fever and violent exercise. But how much margin? Voigt in the last century fell into the error of assuming that because the average German workman consumed 118 grams of protein daily, this could be accepted as the adequate level. Subsequent research has shown that this is a luxus consumption level. Modern students of nutrition may be in danger of falling into the same error by assuming that because doctors, students and laboratory workers ordinarily consume a diet which leads to a plasma ascorbic acid level of more than 0·8 mgms. per cent., or a saturation test result of more than 40 per cent., these intakes are, therefore, the desirable ones. They may represent a luxus consumption level. No matter how desirable such levels may be we are not justified in saying that health necessarily suffers if they are not attained.

These biochemical tests undoubtedly represent the only way in which the role of dietary deficiency can be separated from the role of other factors in the production of malnutrition. They give the promise of quantitative knowledge about vitamin and mineral metabolism. But before they can be fully applied the adequate level of intake must be determined by some other methods.

This difficulty of principle applies to all biochemical tests of this nature. It can probably only be finally solved by demonstration that physical development, functional efficiency and resistance to disease and strain in a group of individuals is not increased by further additions to an experimental diet administered for long periods while the individuals are exposed to all the strains of ordinary life. Such an ideal experiment is clearly impossible for a long time to come. Its difficulties are clearly shown in the experiment of Jokl and Suzman (1940). Until some such data are available a considerable amount of the remedies for malnutrition must be tentative when viewed from the scientific angle.

## A Nutrition Programme

On the other hand the evidence is incontrovertible (Brock, 1943) that a great deal of malnutrition exists in South Africa even though its precise extent has not been susceptible to scientific demonstration. It is also certain that the consumption of grossly inadequate diets is the main factor in the production of this malnutrition. Should the programme for correction of malnutrition wait on further scientific data? The answer must surely be no. The only possible plan is to reorganise the economic life of the country in such a way that there is a parallel rise in purchasing power of the population and increased production of foodstuffs, especially protective foodstuffs. Simultaneously there must be a national campaign of education in food values. Food subsidies will be required in the transition stage. An adequate diet has been defined by the National Nutrition Council (1942). It must be admitted that strictly scientific proof that each item in this scale is neither in the inadequate nor in the luxus consumption range is still lacking. But action cannot wait for this proof. The scale is in line with similar scales accepted by international agreement through the Health Organisation of the League of Nations, and the Nutrition Council has stated that it expects to revise the scale upwards rather than downwards as further knowledge accumulates.

## Acknowledgement

We are indebted to the Union Health Department for financial support of the Cape Nutrition Survey.

## REFERENCES.

Baumann, W. E. and Brock, J. F.: *S.A.J.Med.Sci.* **7**: 212 (1942).

Berliner, M. L.: *Am.J.Opthalmol.* **25**: 302 (1942), quoted in *Nutrition Abs. and Reviews*, **12**: 294 (1942).

Brock, J. F.: *Clinical Proceedings.* **1**: 78 (1942).

Brock, J. F.: *S.A.Med.J.*, **17**: 219 (1943).

Brock, J. F. and Latsky, J. M.: *S.A.Med.J.* **16**: 255 (1942).

Crandon, J. H., Lund, C. C. and Dill, D. B.: *New Eng.J.Med.* **223**: 353 (1940)

Fox, F. W.: *Brit.Med.J.* (1): 311 (1941).

Fox, F. W.: *Proc.Tvl.MineMed.Off.Assoc.* **19**: 249 (1940).

Fox, F. W. and Dangerfield, L. F.: *Ibid.* **19**: 267 (1940).

Göthlin, G. F., Frisell, E. and Rundquest, N.: *Acta.Med.Scand.* **92**: 1 (1937).

Hecht, S. and Mandelbaum, J.: *J.Am.Med.A.* **112**: 1910 (1939).

Jokl, E. and Suzman, H.: *Proc.Tvl.MineMed.Off.Assoc.* **19**: 289 (1940).

Jones, P. H.: *J.Roy.Stat.Soc.* **101**: 1 (1937).

Kark, S. L. and Le Riche, H.: "Report of Bantu Nutrition Survey." *S.Afr.Med.J.* (1943).

Kruse, H. D.: *Pub.HealthRep.Washington*, **56**: 1301 (1941).

Latsky, J. M.: *S.Afr.J.Med.Sci.*, **7**: 217 (1942).

Latsky, J. M., Richardson, A. R. and Brock, J. F.: Read before the *Roy.Soc.S.Af.* (June 1943).

*Lancet* editorial: Feb. 28th, p. 265 (1942).

McCarrison: *Brit.Med.J.* **1**: 256 (1937).

National Nutrition Council Dietary Standards: *S.A.Med.J.* **16**: 291 (1942).

Pemberton, J.: *Lancet*, **238**: 871 (1940).

Portnoy, B. and Wilkinson, J. F.: *Brit.Med.J.* (1): 554 (1938).

Suzman, M. M.: *Clinical Proc.* **1**: 205 (1942).

Sydenstricker, V. P., Sebrell, W. H., Bleckley, H. M. and Kruse, H. D.: *J.Amer.Med.Assn.*, **114**: 2437 (1940).

Thomson, A. M., Griffith, H. D., Mutch, J. R. and Lubbock, D. M.: *Brit.J.Ophthalmology* **23**: 461 and 694 (1939).

Wetzel, N. C.: *J.Am.Med.A.* **116**: 1187 (1941).

Wright, I. S., Lilienfield, A. and MacLenathen, E.: *Arch.Int.Med.* **60**: 264 (1937).

Youmans, J. B.: Nutritional Deficiencies. Lippincott (1941).

# THE EFFECT OF MIELIEPAP (MIELIE MEAL PORRIDGE) AND AMAAS (SOUR MILK) ON THE GROWTH OF ALBINO RATS

BY

C. Gilbert, J. Gillman and J. Mandelstam,
*Dept. of Anatomy;*
T. Gillman,
*Dept. of Clinical Pathology, University of the Witwatersrand*
and
L. Golberg,
*S.A. Institute of Medical Research, Johannesburg.*

*Read 29th June, 1943.*

South African Journal of Science, *Vol. XL, pp. 282-284, November, 1943.*

# ARCHAIC CHIPPED PEBBLE AND FLAKE INDUSTRIES FROM THE OLDER GRAVELS OF VARIOUS SECTIONS OF THE VAAL VALLEY

BY

The Abbé Henri Breuil,
*Membre de l'Institut de France.*
*Bureau of Archaeology, Department of the Interior.*
*Hon. Prof. of Archaeology, University of the Witwatersrand.*

*Read 29th June, 1943.*

In the diamond producing region of the Vaal River valley the slopes of the valley at different heights above the 50-ft. terrace contain quartzitic and chert gravels, in medium- or small-sized pieces, unequally distributed through clayish red sand, which was produced by the decomposition of less durable elements. These are the "red" or "potato" gravels described by van Riet Lowe in his memoir on "The Archaeology of the Vaal River Basin" (1937). Because of their shallowness, these gravels are easily exploited by diamond-diggers.

In the Windsorton and Barkly West regions three levels in the "potato" gravels can easily be noted, the lowest between 60-80 feet above the Vaal, another about 150 feet above, and a third about 200 feet above. We had no chance of studying any higher levels, though they do exist in other places. We collected mostly from dumps left by diggers, but the physical condition of a great many of the specimens seems to indicate that they formed an integral part of these gravels because they are very worn, and may have been of earlier date and redeposited after being flaked, or they are less worn and therefore contemporary.

The Stellenbosch and more recent series collected apparently *in situ* in disturbed or redeposited gravels of the highest level (for example, 300 feet above the Vaal and 20 miles north of Bloemhof at Koosfontein) can be recognised at a glance by their sharp arrisses and old intensive weathering invariably more marked on one face than on the other. Such implements were introduced into the shallow surface gravels either by man or nature at a later date and then covered by red (Kalahari) sand. Those specimens which actually come from the older gravels are physically quite different and morphologically more elementary.

There are many pebble tools, chipped at one end or round the sides, or both, either on one face or more, seldom on both. A few flakes and some pebble cores are found with them.

On approaching the 50-ft. level, bigger and more clumsy quartzite flakes increase in number. These are associated with small proto-types of bifaced pebble tools and a very few bifaced archaic hand-axes of the same material, recalling those which are so numerous in the 50-ft. terrace at Vereeniging. It is curious to note that, although the younger gravels of the Vaal, which were derived from boulders of diabase and andesite which formed the raw material of so many thousands of tools with a more advanced Stellenbosch technique, are so close to the older (quartzitic) gravels, no true Stellenbosch tools of this material are found in the 60-80-ft. terrace.

Far higher upstream, close to the Amcor factory near Vereeniging, Professor van Riet Lowe and I found patches of gravel on the wide 100-ft. terrace, which is of tough ferruginised conglomerate superposed on dwyka tillite with large boulders in a matrix of whitish clay. In certain places these Vereeniging older gravels of the 100-ft. terrace contain a great number of worked quartzite tools, with a few pebble implements, a good many cores and a mass of usually rather rough flakes, some of which are trimmed.

The industry of the 100-ft. terrace at Vereeniging is certainly different from that found in the older gravels at Windsorton and Barkly West. It is chiefly a flake industry. What relation, either in age or of an ethnographical origin, exists between the two groups is difficult to say at the moment. Indeed, the distance between the two areas examined in the valley is great, being about 250 miles in a straight line, with several dams and rapids in the river between the two, and a very extensive survey would be necessary to fix the correlation of the various terraces of older gravels downstream with the single 100-ft. level at Vereeniging.

At any rate, it is certain that in both cases we are dealing with extremely ancient types of tools, far older than those of the Stellenbosch cycle, which belongs to the 50-ft. and more recent terraces described by me in this Journal (1943).

It is interesting to compare these facts with those I noted in Portugal with Mr. Zbyszewski on the 90-metre beach north of the Sierra da Sintra, where we found a large pebble and flake industry similar to those recorded in Kenya, Uganda and the Southern Congo.

It would be unfair not to mention here that similar objects recognised as pre-Stellenbosch have already been published by other discoverers in various parts of South Africa. Captain Jan Smuts has published his notes on this subject as regards the Pretoria region, and he also realised that there were different varieties of these primitive industries (1938). On the other hand, D. R. Macfarlane found similar industries near East London at the base of a clay level earlier than the Stellenbosch tools of the same region (1935).

## REFERENCES.


(¹) VAN RIET LOWE, C.: "The Archaelogy of the Vaal River Basin" *Geol. Memoir No. 35.* Govt. Printer, Pretoria (1937).

(²) BREUIL, H.: "An Industry with Clacto-Abbevillian Facies from the 45 foot Terrace of the Vaal at Vereeniging." *This Journal* **40** 287-288 (1943).

(³) SMUTS, J. C. JUN.: "Past Climates and Pre-Stellenbosch Stone Implements of Rietvlei (Pretoria) and Benoni." *Trans.Roy.Soc. S.Afr.*, **25:** IV, 367-388 (1938).

(⁴) MACFARLANE, D. R.: "Evidence in support of a Pre-Chellean Culture from East London Clays." *This Journal*, **32:** 537-550 (1935).


# THE CREST ON THE PILLAR OF THE DIAZ CROSS


BY

JOHN HARCUS.


*Read 29th June, 1943*

# PRIMROSE RIDGE WEST CULTURE


BY

JOHN HARCUS


*Read 29th June, 1943.*

South African Journal of Science, *Vol. XL, pp. 285-286, November, 1943.*

# ON THE PRESENCE OF QUARTZITES MECHANICALLY BROKEN (SOMETIMES SIMULATING HUMAN WORKMANSHIP) IN THE DWYKA TILLITES AND THEIR DERIVATION IN THE OLDER GRAVELS OF THE VAAL

BY

The Abbé Henri Breuil,

*Membre de l'Institut de France.*

*Bureau of Archaeology, Department of the Interior.*

*Hon. Prof. of Archaeology, University of the Witwatersrand.*

*Read 29th June, 1943.*

This note deals with no great fresh developments, but I feel that I should inform South African prehistorians of a series of recently discovered facts which are useful to know in order to avoid errors in interpretation.

Having had many opportunities of studying mechanical action in Europe, such as the breaking of pebbles carried down by the ancient Swiss glaciers (in the Würmian moraine of Gunsbach at Fribourg) or by the Pyrenean glaciers (in the Rissian moraine of Le Picon near Montrejean, Haute Garonne), in the Baltic moraines containing flints from Holland and South-Eastern England, or in moraines of all ages containing quartzites in the vicinity of Comrie, Perthshire, and Inchnadamph, Sutherland, Scotland, I felt sure that the primary moraines of Dwyka tillite formation would produce comparable phenomena in the older gravels of the Vaal.

This proved to be true when Professor van Riet Lowe and I, on the 20th May, 1943, had occasion to examine the tillite with big boulders and small material in the foliated levels (light in colour, white or pale yellow) which form the base of the 100-ft. terrace of the Vaal at Vereeniging near the Amcor factory. In a fairly extensive quarry on the side of the road opposite the factory, we noticed, besides the large striated boulders, a good many small subangular blocks, also striated, which had been dug out during quarrying but which were obviously derived from the lower undisturbed dwyka conglomerate. The surfaces of these blocks were nearly all mechanically split, and these breakages had even produced flakes. Most of them come from the destruction of an unweathered bed of white quartzitic sandstone. These mechanical fractures are due to the considerable pressure suffered by the rocks during their transport by ice. This pressure produced two types of wide facetted trimming, some having a rather flat bulb and the facetting over-

lapping due to flakes being detached at an almost vertical and sometimes even an obtuse angle. Others have bipolar splintering, obviously due to pressure on opposite faces of a wedged block.

It sometimes happened that this process produced multiple parallel rather narrow facets, with a steep convex curve easily recognisable. There was also a small ovoid flat pebble of indurated schist entirely covered with fine parallel striae, broken across with a double concave fracture by the same process.

Knowing these facts, a re-examination of the series collected was necessary, whether they be from the 100-ft. terrace at Vereeniging where the older gravels overlie the tillite, or from the 50-80-ft. terrace of " red " or " potato " older gravels at Windsorton. The older gravels at Windsorton contain a large collection of pebble implements and primitive flakes, among which we have only found three identical specimens similar in type of fracture and scratching to those from the dwyka of Vereeniging, but which have undergone some later flaking, different in origin and possibly human.

We must therefore always bear in mind throughout all zones of African cultures the possibility of a single or of several disturbances of glacial material containing pebbles broken by the primary ice, mechanical facets being produced by natural action.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 287-288, November, 1943.*

# AN INDUSTRY WITH CLACTO-ABBEVILLIAN FACIES FROM THE 50-FOOT TERRACE OF THE VAAL AT VEREENIGING

BY

THE ABBÉ HENRI BREUIL,

*Membre de l'Institut de France.*

*Bureau of Archaeology, Department of the Interior.*

*Hon. Prof. of Archaeology, University of the Witwatersrand.*

*Read 29th June, 1943.*

At Vereeniging the latest aggradation of the older gravels of the Vaal lies on the 50-ft. terrace now artificially exposed on both banks of the Klip River near its junction with the Vaal. These gravels are almost exclusively quartzitic mixed with angular red sand. They therefore belong to the older gravels of the Vaal and are earlier than the tectonic phenomena which, according to Du Toit (1933), forced the river to deepen its bed at the expense of the diabasic levels in the bed of the river. It was this (Ventersdorp) diabase which served as raw material for the great mass of Acheulean-type Stellenbosch tools of the younger gravels which were aggraded later.

The site at Vereeniging, known as the Klip River Quarry, was discovered by Professor van Riet Lowe in 1920 and was first visited by me with him in 1929. It was re-examined by Professor van Riet Lowe and his collaborators during their extensive geo-archaeological survey of the Vaal River valley during the years 1936 and 1937 (1937). The implements collected from the body of the gravels were quite rightly assigned to the earliest division of the Great Hand-axe Culture and are referred to the Stellenbosch I Division of that culture. Because this was the only site from which Stellenbosch I tools were recovered *in situ*, and because no such tools had been recovered from the older gravels either here or elsewhere along the Vaal. it was felt at the time that the deposit possibly belonged to the beginning of the aggradation of the younger gravels, which contain vast quantities of remains of the Great Hand-axe Culture, rather than to the end of the aggradation of the older gravels, and it was therefore assigned to the younger group of gravels. As a result of later work, however, and as a result of my own inspection of the deposits with Professor van Riet Lowe recently, I am satisfied that the Klip River Quarry gravels belong to the last phase of aggradation of the older gravels and not to the earliest phase of the younger gravels. They are

lithologically inseparable from the great body of older gravels that extend for many hundreds of miles down the Vaal River valley from Vereeniging to Barkly West and beyond.

The material used in the industry of the 50-ft. terrace gravels at Vereeniging is exclusively quartzitic. It differs completely in form and trimming technique from that employed by the makers of hand-axes in the more recent (lower) levels. The flakes have a broad flat striking platform, more often at the base than on the side. Though many of the hand-axes are made from pebbles, a greater number are made from heavy wide-angled flakes by a very primitive *bloc-en-bloc* anvil technique. These gravels also contain series of tools of successive ages, some very worn and earlier than the gravels, others less weathered and contemporary, and yet others which are perhaps a little later and only slightly worn. A certain development is noticeable between one series and another.

Loose sandy levels that overlie the gravels yielded Fauresmith and Middle Stone Age tools, also in quartzite.

An examination of a collection of stone implements made by the late Dr. T. N. Leslie in the younger gravels in the bed of the Vaal at Vereeniging shows the specimens to be identical with types found in the younger gravels at Riverview Estates, opposite Windsorton, at Pniel, at Barkly West and elsewhere along the Vaal.

These facts show that before the aggradation of the younger gravels, and before the great tectonic movements which upset East Africa during the later stages of the development of the Great Rift Valley, the effect of which was felt as far south as the Vaal, the industry which flourished in the Union was an archaic Stellenbosch of Clacto-Abbevillian facies described by Professor van Riet Lowe as Stellenbosch I (1937). It is identical with that discovered on the 90-meter Sicilian beach at Abderahman, near Casablanca, in Morocco, which I have examined, and which was recently described by Neuville and Rühlmann (1941). This is separated from the 30-metre (Acheulean) beach by the 60-metre beach.

The time which separates the aggradation of the older gravels in the 50-ft. terrace at Vereeniging from the younger gravels in the Vaal is therefore very considerable, geologically speaking.

## REFERENCES.

Du Toit, A. L.: "Crustal Movement as a Factor in the Geological Evolution of South Africa." *S.A.Geog.Jour.*, 16: (1933).

Van Riet Lowe C.: The Archaeology of the Vaal River Basin. Geol. Memoir No. 35, Govt. Printer, Pretoria (1937).

Neuville, R. and Rühlmann, A.: "La Place du Paléolithic Ancien dans le Quaternaire Marocain." *Inst.des Htes. Etudes Marocain*, No. 8 (1941).

South African Journal of Science, *Vol. XL, pp. 289-295, November, 1943.*

# FURTHER NOTES ON THE MAKAPAN CAVES.

BY

C. van Riet Lowe,

*Director, Bureau of Archaeology, Department of the Interior; Professor of Archaeology, University of the Witwatersrand.*

*With 1 Text-figure.*

*Read 28th June, 1943.*

## 1—Introduction.

Five years ago I published an archaeological note on the Makapan Caves (1938). This included illustrations of a hand-axe and a cleaver recovered from the fossil- and implement-bearing breccias in the Cave of Hearths on the farm Makapansgat, No. 347, in the Potgietersrust district of the central Transvaal. The possibility of the occupation of this cave, not only during the Earlier Stone Age, but also during the Middle Stone Age was suggested, while emphasis was laid on the fact that much more exhaustive investigation was necessary. The unhappy years that followed precluded the possibility of extensive investigations, but occasional visits during these years have taught us a great deal more than we knew five years ago.

In 1940, the Bureau of Archaeology in collaboration with the Transvaal Museum, devoted some time to a close examination of the breccia that had collapsed from below the principal hearth in the Cave of Hearths. This material had previously been removed to an adjacent cave for safety. It was all derived from artificially accumulated layers and hearths that lay between the original stalagmitic floor at the base of the deposits and the most extensive and consolidated hearth which now forms the ceiling of the cave some twelve feet above the original floor level. The material that fell from this space includes about six hundred tons of fossil- and implement-bearing breccia—a deposit in itself sufficiently great to suggest the possibility of the presence within it of elements of more than one period of occupation and, therefore, of more than one material culture.

Despite the difficulties encountered in freeing the fossils and artifacts from the small quantity of the breccia it was possible to break up and examine in the time at his disposal, Mr. B. D. Malan, who was in charge of the work in which he was very ably assisted by Mr. A. G. White of the

Transvaal Museum, recovered several hundreds of flakes, cores and fabricators together with a few implements that show that the earlier and possibly the first human occupants of the cave enjoyed a material culture that belongs essentially to the Earlier Stone Age. The bifaced tools that I had previously recovered, characterise an advanced expression of the great hand-axe group of cultures—possibly late Stellenbosch—while the cores and flakes reveal a mastery over a very crude or proto-Levallois technique that recalls the Tayacian of Europe as described by Breuil (1932).

This primitive Levallois or Clacto-Levallois as it should perhaps be called, is exceedingly interesting and puzzling. It may be an integral part of the Great Hand-axe Culture complex just as the proto-Levallois is an integral part of the same complex at Victoria West and elsewhere in the Union, but, apart from the hand-axes and cleavers, the Makapan material includes nothing that resembles that recovered at Victoria West and elsewhere where the Victoria West or true proto-Levallois technique is found as an integral part of the Stellenbosch Culture. This Cave of Hearths material is quite distinct from and cruder than that from Victoria West and cannot be satisfactorily matched in the Union. The tools themselves present another difficulty. Some of the cleavers are on side-flakes that appear to have been derived in the Victoria West I (or Proto-Levallois I) manner. These naturally lead one to suspect that the makers of these tools were masters of the Victoria West technique—yet we have no Victoria West *débitage*. The waste flakes and cores that we have, are completely atypical We must, therefore, await more detailed investigations before this difficult and all-important issue can be clarified.

The 1940 expedition also recovered three throwing-stones or bolas—specimens that one usually associates with the developed Levallois of the Middle Stone Age. These give rise to another problem that demands a close re-examination of the cores and flakes. Only one of the many cores recovered approaches the Levallois. It is high-backed and radially trimmed, but is not characteristic of the Levallois. It is essentially crude. The remainder are atypical. When we re-examine the flakes we find that the general tendency is toward wide-angled, broad and thick types with plain striking platforms. Those that include facetted platforms are in a decided minority and even in them the preliminary preparation appears to have been confined to the removal of two flakes only; the blow to remove the final flake having been struck on the arris that separates the scarbeds of the two preparatory flakes. True Levallois characteristics are, therefore, all but absent. The few that may be present (and with these I include the bolas), may have been derived from the uppermost levels of the collapsed material and thus belong to the level of the great hearth and the material that has yet to be recovered from

it and from the deposits immediately above it. This may prove to be Middle Stone Age.

At one time it was suspected that many of the thick, stubby wide-angled flakes may have been struck from hand-axes and cleavers during blocking-out processes on an anvil or during the shaping of these tools. This may indeed occasionally be the case, but the presence of so many cores and the obvious derivation of so many flakes from these cores nullifies the importance of the suspicion. While some of the flakes may have been struck during the shaping of hand-axes, the great majority were very obviously not derived in this manner.

The materials include quartzite, quartz and a sprinkling of indurated sandstone and shale. Large numbers of tools and artifacts show damage by fire and quite a number are weathered. Some of the latter have slightly oxidised surfaces; others have rounded or water-worn arrisses that show that they were brought into the cave after exposure to wind and running water outside. When freed from the lime incrustations, the vast majority of the remainder are in mint condition, due no doubt, to the shelter afforded by the cave in the first instance and to the protective coating of lime in the second.

We can, therefore, sum up the material recovered from the Cave of Hearths by saying that whatever future investigation may reveal: (i) the cave was occupied by makers of well advanced Stellenbosch hand-axes and cleavers, and (ii) either (a) the folk who made those tools were masters of a crude Levallois or Clacto-Levallois technique, or (b) this technique was not an integral part of the core-cum-flake hand-axe culture.

If this Clacto-Levallois, i.e., Tayacian-like material, is not an integral part of the hand-axe culture—as the Victoria West or Proto-Levallois I and II are of the Vaal Stellenbosch III and IV (1937)—it can only represent the presence of a people who during Earlier Stone Age times, possessed a material culture that differed appreciably from that enjoyed by the makers of hand-axes and cleavers. This possibility introduces a vertical division into the material cultures possessed by men during the Earlier Stone Age in South Africa, i.e., to a state of affairs similar to that which is believed to have existed in Old Palaeolithic times in Western Europe and other parts of the Old World. Some believe it also existed here. Van Hoepen has stressed the possibility (1938) and Smuts has also referred to it (1938). My own view is that the issues implied by this so-called vertical division between core cultures on the one side and flake cultures on the other, can be unduly stressed in that it is impossible, as the Abbé Breuil recently remarked to me, to have a core culture without flakes or a flake culture without cores. Indeed, even in the most primitive pre-Stellenbosch and pre-Abbevillian pebble or so-called simple core cultures, it is improbable that the flakes struck during the trimming of the pebbles were not utilised. Even the Kafuan or pre-African

Abbevillian core culture of Uganda has its flakes and flake tools throughout its four-phase development, despite the fact that the vast majority of tools hitherto recognised and described are on cores such as later characterise the Oldowan Culture of East Africa (1936). We think of the Kafuan and Oldowan cultures as "core cultures" simply because the great majority of tools hitherto recognised are on cores, but the important issue: the object of the tool-maker, is elusive. Before we can refer a group of artifacts to a core culture or a flake culture, we must be able to recognise the principal aim of the maker of the artifacts, i.e., we need to be able to say whether his main object was to make instruments of flakes or of cores. This is no simple matter. Our greatest difficulty arises in the allowances we must make for differences between assemblages recovered on open sites (where fully representative material cannot be expected) and those found in sealed (cave) sites. These may be most marked and as the Cave of Hearths is only the second discovery of Stellenbosch hand-axes found sealed in a cave in South Africa, we still have a great deal to learn about the culture. The question, so far as we are concerned, must, therefore, remain an open one while the evidence before us is as slender as it is.

## 2—Recent Work.

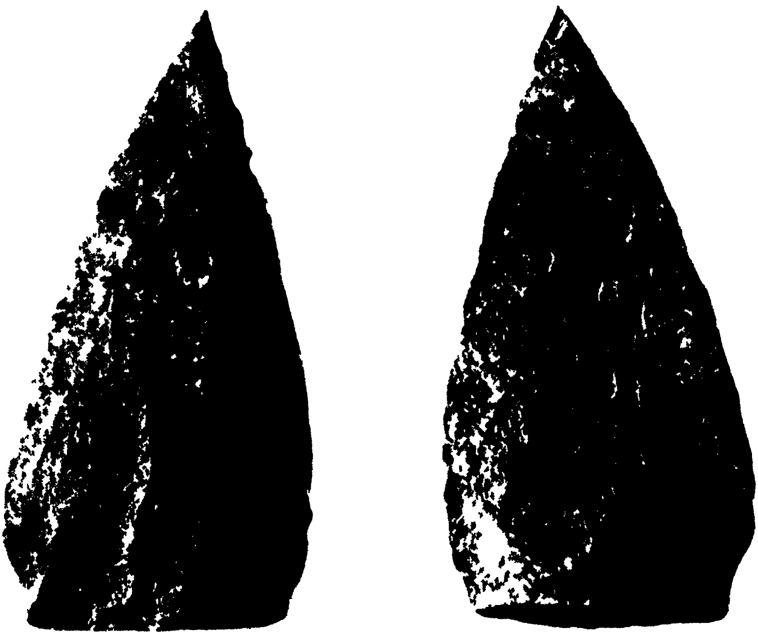
In February, 1943, I revisited the area accompanied by the Abbé Breuil and Mr. B. D. Malan when we re-examined the caves during a week's stay in the neighbourhood. The results of this recent visit may be summarised as follows:—

A. The Cave of Hearths.—Our joint investigations yielded nothing new, but the Abbé Breuil stressed two important impressions: (i) the marked preponderance of Tayacian affinities revealed by the great mass of material recovered from the lower layers and (ii) the striking superficial resemblance between the deposits and those of Chou Kou Tien—especially the phosphatic breccias and layers of ash of various colours.

As the hand-axes and cleavers we have were all found on top of the breccia that collapsed between my first and second visits in 1937, or occurred lying loose among the fallen blocks, and as Mr. Malan found no bifaced tools in the breccia he developed, but only very crude proto- or pseudo-Levallois-type cores and flakes undoubtedly recovered from the body of the lower and lowermost deposits, we reluctantly left the cave with the feeling (i) that remains that recall the Tayacian of Europe occur in the lower levels, (ii) that among the earlier occupants of the cave were makers of hand-axes and cleavers some of which suggest a knowledge of the Victoria West or Proto-Levallois technique that may here be later than the Tayacian types, (iii) that the few possible Middle Stone Age elements recovered may have been derived from layers above the Stellen-

bosch and Tayacian forms, i.e., from the zone of the great hearth that forms the present ceiling of the cave, and (iv) that it is imperative to start systematic investigations as soon as circumstances permit. The task will be a long and tedious one that will need to be spread over many suitable seasons.

B. The Rainbow Cave.—This cave is characterised by a great accumulation of ash stratified from the floor upwards in layers of grey, pink, green, yellow and mauve pastel shades—a deposit that reaches a thickness of over six feet at one side of the cave. The only artifact previously recovered from the adjacent breccia at bedrock was a small very advanced Levallois flake in clear quartz. During our latest visit we re-examined the lowermost breccias, which are also phosphatic in patches, and recovered a number of flakes and blades as well as the point shown in the accompanying photograph.



The assemblage undoubtedly belongs to the Pietersburg variation of the Middle Stone Age as described by Goodwin 1929—a variation about to be raised to the status of a full culture. All the tools and flakes were coated with lime which had to be removed by treatment with hydrochloric acid. The point chosen for illustration is in mint condition; literally as sharp as a needle. The butt and flake surfaces are plain and the edges and upper face have been elaborately trimmed. It measures 2·7in. × 1·8in. × 0·4in. in maximum length, breadth

and thickness and is of felsite, the nearest supply of which is several miles away.

The breccia yielded no traces of the great hand-axe group of cultures of Old Palaeolithic times, nor did it yield any Tayacian forms such as we recovered in quantity in the Cave or Hearths. The material is exclusively Mid-Palaeolithic. The stones used include quartzite, quartz, chert and felsite—a material most favoured by the masters of the developed Levallois technique that forms the basis not only of the Pietersburg Culture of the Central Transvaal, but of the entire Middle Stone Age throughout the sub-continent.

C. The Buffalo Cave, so-called because during an earlier visit Mr. Malan and I recovered the mineralised horns and several fossil bones of the extinct Bos Makapanni (1937)—yielded an indeterminate artifact in quartz; an obvious importation.

### 3—General Observations.

These brief notes make it clear that the breccia-filled limestone caves on the farm Makapansgat were not all occupied at the same time and that there is a very urgent need to keep the fossils, both faunal and human, from each cave not only in separate collections, but also to note the exact position of every specimen found *in situ*. My reasons for stressing this obvious need are due to the fact that during the early stages of commercial exploitation, at least half a dozen deposits were "worked." Of these five are known to contain fossil-bearing breccias. It is unfortunately inevitable that the fossils first recovered and sent to museums should merely have been catalogued as having come from the "Makapan Caves" or from the farm "Makapansgat." These can, therefore, be of general palaeontological interest only. Now that the human occupation of the caves by men of different lithicultural horizons has been established, a repetition of this state of affairs would be most unfortunate.

It is also important to note that the degree of mineralisation of the bones and breccia is not necessarily an indication of relative age. The factors that control the ingress of lime-bearing waters into the deposits vary from cave to cave. Indeed while the caves described are known to have been occupied either by animals or by men at different times during the Quarternary Age, it is possible that others were occupied during Tertiary times.

No cave yielded traces of the Later Stone Age despite the fact that tools that characterise the Smithfield and Wilton Cultures as well as rock paintings, occur sporadically in the neighbourhood. The infilling and sealing processes in the Makapan Caves appear to have been completed before the makers of Smithfield and Wilton tools appeared on the scene.

## REFERENCES.

VAN RIET LOWE, C.: "The Makapan Caves: An Archaeological Note." *This Journal*, **25**: 371-381 (1938).

VAN RIET LOWE, C.: "The Archaeology of the Vaal River Basin." *Geol. Memoir No. 35*, Govt. Printer, Pretoria (1937).

BREUIL HENRI: "*Les Industries à Eclats du Paléolithic Ancien*," *Prehistoire*, **1**: 188 (1932).

VAN HOEPEN, E. C. N.: "Enige Gesigspunte in die Suid-Afrikaanse Argeologie." *This Journal*, **35**: 92-125 (1938).

SMUTS, J. C. JUN.: "Past Climates and Pre-Stellenbosch Stone Implements of Rietvlei (Pretoria) and Benoni." *Trans.Roy.Soc.S.Afr.*, **25**: 367-387 (1938).

LEAKEY, L. S. B.: "*The Stone Age Cultures of Kenya Colony.*" Camb. Univ. Press (1931).

LEAKEY, L. S. B.: "*Stone Age Africa.*" Oxon. Univ. Press (1936).

WAYLAND, E. J. and VAN RIET LOWE, C.: "The Pleistocene Geology and Archaeology of Uganda." Publication held up by war.

GOODWIN and VAN RIET LOWE: "The Stone Age Cultures of South Africa. *Ann.S.A.Mus.*, **27**: 109 et seq. (1929).

MALAN, B. D.: "The Middle Stone Age in the Central Transvaal." In preparation.

BROOM, R.: "Notices of a few new Fossil Mammals from the Caves of the Transvaal." *Ann. and Mag. of Nat.Hist.*, Ser. 10, **20**: 509 (1937).

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 296-302, November, 1943.*

# EDGED DISCS AND ARMRINGS

BY

A. J. H. GOODWIN,

*Read 29th June, 1943.*

During the past few years I have been working on a survey of the bored stones of South Africa, and in the course of this work my attention has been drawn somewhat forcibly to a number of interesting and important facts concerning these various but analogous implements. One or two of my findings may be attributed to chance, but in certain instances this element of chance becomes so remote that it can hardly be said to play a very important part. Under this latter heading may be placed the accumulation of known facts concerning the distribution and the sizes of certain discus-like stones generally regarded as armrings, or as armrings in the making.

In the following paper I have brought together the relevant figures, and I discuss these, not so much with the intention of making any final contribution to science, but to elicit further and more exact information concerning the sizes, distribution and the cultural associations of these stones. I here refer to these implements by the non-committal name of "edged discs." The only term that may need explanation is "index," which refers to the relationship of the thickness of the implement to the external diameter, expressed as a percentage. It is therefore the quotient of the fraction:

$$\frac{\text{Thickness x 100}}{\text{External diameter}}$$

The edged disc consists of a stone lens, ground carefully to shape and finally bored. It generally has an index below 30 per cent., and may be bi-convex, or less commonly plano-convex. Variation in size is very considerable, ranging from 6·0 cms. to 13·3 cms., a variation of well over 100 per cent. The "stone armring" has in all cases been made from such a disc by increasing the bore by careful rimming until only the outer rim of the lens remains. The section of the "armring" thus consists of an isoscelean triangle, the base towards the centre and the acute apical angle outward, forming the perimeter of the ring.

The only two important measurements are the external and the internal diameters (the bore), the first indicating the maximum possible size of the bangle, the second showing how

far the process of rimming had gone. The external diameter is the only common figure for comparisons between edged discs and armrings. The index is given, but only to show the general relationship between diameter and thickness. It is obvious that as the aperture bored into a lens increases, so the thickness, and hence the index, decreases. An illustration of the armring may be found in Van Riet Lowe's Smithfield paper (1). Burkitt has also depicted a small fragment of one (2).

The modern European technique of grinding glass lenses by hand consists in rubbing two flat surfaces of glass together until one becomes increasingly convex and the other shows a concave depression. How these prehistoric lenses were made it is so far impossible to say. I have never observed any concave surface of a type suggesting that it was so used. The presence of such a depression, either in standing rock or smaller hand-material, would yield interesting evidence. I know of no example of an unbored lens of this type.

Sites are listed here under provinces, and the lists are not so complete as I would have wished. No specimens are known to me from the Transvaal. In certain cases photographs have been used to obtain measurements. Four or five examples from the McGregor Museum, Kimberley, have been taken from photographs by Mr. Duggan-Cronin with the help of a scale provided by Miss M. Wilman. The error in such instances is slight. Two examples have been taken from an early paper by S. Schonland (3). Only external and internal diameters are given. In addition, Lowe's illustration and measurements are used for the specimen he has depicted, but the provenance is not given, and the specimen has since been destroyed by fire. De Kiel Oost is presumed to be the origin, but Koffiefontein is an alternative. One or two specimens have been taken from Dunn (4), using the scale he gives there.

The following abbreviations are employed to denote sources:—

| | |
|---|---|
| A.M.G. | Albany Museum Collection, Grahamstown. |
| E.L.M. | East London Museum Collection. |
| M.M.K. | McGregor Museum Collection, Kimberley. |
| N.M.P. | Natal Museum Collection, Pietermaritzburg. |
| P.E.M. | Port Elizabeth Museum Collection. |
| S.A.M. | South African Museum Collection, Cape Town. |
| S.I. | Stone Implement Collection at the Durban Museum and Art Gallery. |
| T.M.P. | Transvaal Museum Collection, Pretoria. |
| U.C.T. | University of Cape Town Archaeological Collection. |
| W.U.A. | Witwatersrand University, Anatomy Department Collection. |

The remainder, from private collections, will explain themselves. My thanks are due to all sources of material, and it is hoped that further material will be submitted to me in the near future:—

| | Diam. | Ht. | Ind. | Mouth. | Cent. | |
|---|---|---|---|---|---|---|
| **Swaziland:** | | | | | | |
| S.I., 26 ... ... ... ... | 13·1 | 2·1 | 16·0 | 5·7 | 4·5 | |
| | | | NATAL. | | | |
| **Durban:** | | | | | | |
| S.I., 25 ... ... ... ... | 8·9 | ·9 | 10·1 | 5·8 | 5·2 | |
| **Bushman's River.** | | | | | | |
| T.M.P., 1865 | 13·3 | 2·9 | 21·9 | 8·1 | 5·1 | |
| **Kranskop:** | | | | | | |
| N.M.P., 2056 ... ... | 12·1 | 1·7 | 14·2 | 6·0 | 4·9 | ·24 Kgs. |
| **Uvongo:** | | | | | | |
| S.I., 7 ... ... ... ... ... | 10·9 | 1·8 | 16·5 | 3·4 | 1·8 | 10 feet deep. |
| | | ORANGE FREE STATE. | | | | |
| **"O.F.S.":** | | | | | | |
| S.A.M., Bain ... ... | 11·3 | 2·8 | 24·7 | 4·5 | 4·4 | |
| **Koffiefontein:** | | | | | | |
| B.A.J., 64/38 ... ... | 6·8 | 2·0 | 29·4 | 2·6 | 2·0 | |
| U.C.T., 35/157 ... ... | 7·3 | 1·2 | 16·4 | 2·1 | 1·6 | |
| W.U.C., 1100/G ... | 7·7 | 1·5 | 19·0 | 3·8 | 2·7 | |
| W.U.A., 1100/H ... | 8·8 | 1·4 | 16·0 | 3·6 | 2·8 | |
| W.U.A., 228 ... ... ... | (11·6) | 1·6 | 13·8 | 6·8 | 5·6 | |
| M.M.K., 1990 ... ... | 10·6 | 3·1 | 29·2 | 3·5 | 2·5 | Sandstone. |
| M.M.K., 1414 ... . . | 9·9 | — | — | 6·6 | 5·3 | From Duggan-Cronin. |
| **De Kiel Oost:** | | | | | | |
| B.A.J., 11/40 ... ... | 9·8 | 3·0 | 30·6 | 3·8 | 2·0 | |
| B.A.J. (Burnt) ... ... | 10·0 | ·8 | 8·0 | (7·0) | 6·4 | From Lowe. |
| **Smithfield:** | | | | | | |
| S.A.M., 1143 ... ... | 9·1 | 1·7 | 18·7 | 2·2 | 1·7 | |
| **Marseilles:** | | | | | | |
| U.C.T., 23/182 ... ... | 12·1 | 2·0 | 16·5 | 5·2 | 4·7 | (Oval hole, 5·2 x 4·7 cms.). |
| | | GRIQUALAND WEST AND VAAL. | | | | |
| **Griqualand West:** | | | | | | |
| S.A.M., 4367 ... ... | 10·5 | 2·4 | 22·8 | 6·2 | 5·5 | |
| **Modder River:** | | | | | | |
| S.A.M., 1132 ... ... | 8·0 | 2·3 | 29·0 | 2·6 | 1·2 | |
| **Douglas:** | | | | | | |
| S.A.M. ... ... ... . | 9·5 | 3·3 | 34·7 | 2·4 | 1·2 | |
| M.M.K., 258 ... ... | 12·5 | 4·1 | 32·8 | 3·7 | 2·2 | Ss. |
| **Vaal - Orange Confluence:** | | | | | | |
| A.M.G. ... ... ... ... | 10·0 | — | — | — | 1·9 | From Schonland. |
| A.M.G. ... ... ... ... | 11·4 | — | — | — | 5·7 | From Schonland. |
| **Windsorton:** | | | | | | |
| B.A.J., 5/35/55 ... | 9·5 | 1·0 | 10·5 | 5·6 | 5·3 | |
| **Last Hope:** | | | | | | |
| M.M.K., 2002 ... ... | 9·1 | — | — | 6·3 | 5·8 | From Duggan-Cronin. |
| **Kanteen Kop:** | | | | | | |
| M.M.K., 2001 ... ... | 9·6 | — | — | 6·1 | 5·8 | From Duggan-Cronin. |

In addition to these, two anomalous examples come from the McGregor Museum, Kimberley, Nos. 1568 and 1409 respectively. They are both from Koffiefontein. The first is a plain disc of stone, unbored but chipped carefully to a lenticular

shape without signs of grinding (10·5 by 10·2 cms. in diameter). Almost identical, but bored, is the second example from the same site. These two suggest that in certain instances these implements were chipped first, then bored, and presumably might be finally ground. It is hardly possible that grinding and polishing were left until the armring was completed, as this would involve very careful handling of the delicate stone ring.

EASTERN CAPE PROVINCE.

| | Diam. | Ht. | Ind. | Mouth. | Cent. | |
|---|---|---|---|---|---|---|
| Victoria East (Alice): | | | | | | |
| S.A.M., 3826 ... ... | 10·6 | 2·2 | 20·7 | 7·4 | 6·4 | |
| Gcalekaland (Willowvale District): | | | | | | |
| A.M.G. ... ... ... ... | 11·4 | — | — | — | 5·4 | From Schonland. |
| Aliwal North: | | | | | | |
| Dunn ... ... ... ... ... | (7·8) | — | — | — | (4·5) | From Dunn. |
| Coega to Kleinpoort: | | | | | | |
| P.E.M., 614/C ... ... | 11·5 | 4·7 | 40·9 | 4·3 | 1·5 | (Very thick specimen). |

SOUTHERN CAPE PROVINCE.

| | Diam. | Ht. | Ind. | Mouth. | Cent. | |
|---|---|---|---|---|---|---|
| Storms River: | | | | | | |
| S.A.M. ... ... ... ... | 13·0 | — | — | — | ·9 | From Péringuey. |
| Tzitzikamma: | | | | | | |
| P.E.M., 94 ... ... ... | 12·6 | 2·4 | 18·7 | 2·9 | 1·7 | Plano-convex. |
| Knysna: | | | | | | |
| S.A.M., Bain ... ... | 8·5 | 1·9 | 22·3 | 1·9 | 1·1 | |
| | 7·5 | 1·2 | 16·0 | 2·0 | 1·0 | |
| | 6·0 | 1·8 | 30·0 | 2·6 | 1·8 | |
| Sharples, 15 ... ... ... | 9·7 | 2·0 | 20·0 | 2·3 | 1·3 | |
| Platbos, Still Bay: | | | | | | |
| Heese ... ... ... ... ... | 10·7 | 2·4 | 22·4 | 6·2 | 5·5 | Ss. ·23 Kgs. *S.A.J.S.*, XXV, p. 397. |
| Bloembos: | | | | | | |
| Heese, 14 ... ... ... | 8·5 | 3·0 | 35·3 | 2·8 | 1·4 | |
| Stellenbosch: | | | | | | |
| S.A.M., 205 ... ... ... | 6·5 | 1·1 | 16·9 | 1·2 | ·7 | |
| Worcester: | | | | | | |
| Heese, 15 ... ... ... | 7·6 | 2·3 | 30·3 | 2·7 | 1·4 | |
| Cape Peninsula: | | | | | | |
| S.A.M., 105 ... ... ... | 8·6 | 2·5 | 30·0 | 2·3 | 1·1 | Strandfontein. |
| S.A.M. ... ... ... ... | 9·7 | 3·0 | 30·9 | 2·8 | 1·9 | Cape Point. |
| S.A.M. ... ... ... ... | 8·3 | 2·4 | 28·9 | 2·2 | 1·2 | False Bay. |
| Jardine Coll. ... ... | 8·2 | 1·7 | 20·7 | 1·9 | ·95 | Somerset West. Shale. |

ELONGATED EDGED DISCS.

| | Diam. | Ht. | Ind. | Mouth. | |
|---|---|---|---|---|---|
| East London: | | | | | |
| E.L.M., 35 ... ... ... | 18·0 x 14·5 | 4·0 | 6·0 | 4·0 | 1·14 Kgs. Cambridge quarry. Roughly triangular. Worked to an edge on one side of triangle only. |
| Port Elizabeth: | | | | | |
| P.E.M., 615/J ... ... | 11·6 x 9·0 | 3·0 | 3·7 | 2·3 | ·3 Kgs. Shell breccia (Perseverance). |
| Tzitzikamma: | | | | | |
| P.E.M., 94 ... ... ... | 12·0 x 9·8 | 1·9 | 1·9 | 1·2 | ·31 Kgs. Plano-convex. |

These last three are anomalous in various ways, and little evidential value can be attached to them; they merely serve to draw attention to the possibility of further elongated forms occurring. Few, if any, of the "circular" specimens are mathematically circular, and Heese's paper cited under Platbos above shows the range of error to be expected.

## Analysis.

The only figures of practical interest to us here are those in the first and last columns above. These are the external diameter, showing the maximum size of ring that could be expected, and the internal diameter, showing the actual size of ring achieved, or, more briefly, the bore.

We may express these as a simple table, showing the maximum and minimum range of external diameter, the maximum and minimum range of internal diameter, and finally the maximum and minimum range of the great majority of specimens (internal diameter):—

| Area. | External. | Internal. | Majority. |
|---|---|---|---|
| Swaziland and Natal ... ... | 13·3—8·9 | 5·2—1·8 | 5·2—4·5 |
| Orange Free State .. ... | 11·6—6·8 | 6·4—1·3 | 6·4—4·4 |
| Griqualand West ... .. | 12·5—8·0 | 5·8—1·2 | 5·8—5·5 |
| Eastern Cape Province ... | 11·5—7·8 | 6·4—1·5 | 6·4—4·5 |
| Southern Cape Province ... | 13·0—6·0 | 5·5— ·7 | 1·9—1·0 |

If we look more closely into the figures, we see that in the Free State and Griqualand West areas the internal diameters divide themselves into two groups—those between 1·2 and 3·0, and those between 4·4 and 6·0 cms. The Eastern Province series agrees fairly well with those figures.

In the Southern Cape Province we have a very different state of affairs. Here only one specimen (from Platbos, 5·5 cms. internal diameter) exceeds 1·9 cms. in bore, while holes are in two cases less than a centimetre across.

Now let us study some facts about these figures. By experiment a fixed circle of 6·0 cms. is the smallest aperture through which a small woman's hand will pass, while the average is higher than this. The diameter of the ulna and radius together at the narrowest part of the wrist is in the region of 5·3 cms. in the adult. It becomes obvious that of the thirty specimens listed only two specimens could have passed the hand of an adult woman (De Kiel Oost and Victoria East). Once in position (having been placed there earlier in life) on the wrist, only eight could have remained in place until maturity without seriously impeding the use of the wrist, or even deforming the bone at that point. These latter consist of specimens with an aperture greater than 5·1 cms. (2·00789 inches).

It has always been presumed that the edged disc was a stage in the making of the "arm-ring" in all cases and that

an armring was actually intended. Various questions arise; for instance, why have no such rings been found *in situ* in prehistoric burials? Again, why are no such armrings depicted in prehistoric paintings? The only arm and leg ornaments depicted are above the calf and above the elbow and are related to existing Bushman ornaments.

It becomes clear that we may well be dealing with two distinct implements, the one with an external diameter of perhaps 10·0 to 13·3 cms. in extreme range, the other from 6·0 to 10·0 cms. in extreme range. It is perfectly possible that the larger series was intended to be made into a child's bangle with an internal diameter of from 7·0 cms. to 10·0 cms. The others could never have hoped to have a bore greater than 4·0 to 7·0 cms., and in fact few exceed 1·9 cms., or three-quarters of an inch. This latter group is most markedly preponderant in the Southern Cape.

A single specimen, not listed above, from Doorlhof, Bain's Kloof, Cape Province, may make the position clearer. It has been carefully described by Dr. C. H. Heese ([5]) and consists of an edged triangular implement, almost isoscelean and measuring 21·0 cms. in length by 13·6 cms. in width. The hole has an aperture of 2·9 cms. and a minimum diameter of 1·4 cms. It is impossible to regard this as an unfinished armring, and it is evident that we are dealing with a polished implement or ornament. The question therefore arises as to whether we are justified in regarding the majority of our specimens as unfinished armrings, or whether they do not represent a group of implements of the type described by Heese.

As to outside evidence, we know little. Miss M. Wilman, of the McGregor Museum, Kimberley, states that many of the specimens in that collection are known to have come from fresh water springs, and she therefore uses the term "eye of the fountain" to describe them. Whether that term has any foundation in Bushman or Hottentot lore I do not know, but the suggestion is put forward for what it may prove to be worth in the light of future discovery. It would seem unnecesary to grind a stone to a lenticular or plano-convex shape merely to keep the eye of a fountain uncontaminated.

Péringuey ([6]) in a footnote suggests that the edged disc may be analogous to the Indian *tchakra*, a metal throwing discus, stone examples of which he cites from India and Cochin-China and from France and Italy, presumably parent to the Greek discus. Many specimens are in soft stone and would certainly show chipping from usage if this were their use.

Another analogy may be found among the stone-headed clubs used among the tribes of British New Guinea ([7]). It is quite possible that the edged disc might have been so employed and would have proved an extremely efficient club, but prehistoric skulls show no evidence of its use.

The only evidence in original literature concerning the use of armrings (not necessarily stone) is found in "Alexander's Travels" (8) where he states that "the Bushman, to make his arm heavier for throwing the assegai, wears his trophy rings."

Whatever their uses may have been, I have retained the two terms, "arm-ring" and "edged-disc," in the hope that further evidence will clear the position.

## DISTRIBUTION.

| Aperture under 3 cms. | Aperture over 4·4 cms. |
|---|---|
| Uvongo. | Swaziland. |
| Koffiefontein. | Durban. |
| De Kiel Oost. | Bushman's River. |
| Smithfield. | Kranzkop. |
| Modder River. | "O.F.S." |
| Douglas. | Koffiefontein. |
| Vaal-Orange Confluence. | (De Kiel Oost). |
| Coega-Kleinpoort. | Marseilles. |
| Storms River. | "Griqualand West." |
| Tzitzikamma. | Vaal-Orange Confluence. |
| Knysna. | Last Hope. |
| Bloembos. | Kanteen Kop. |
| Bain's Kloof. | Windsorton. |
| Stellenbosch. | Victoria East. |
| Worcester. | Gcalekaland. |
| Strandfontein. | Aliwal North. |
| Somerset West. | Platbos, Still Bay. |
| False Bay. | |
| Cape Point. | |

## BIBLIOGRAPHY.

(1) VAN RIET LOWE: *Annals S.Afr.Mus.*, **27**: pl. xviii 1, and p. 164 (1929).

(2) BURKITT, M. C.: *South Africa's Past in Stone and Paint*, **17**: 6.

(3) SCHONLAND, S.: "Stone Implements in Albany Museum." This *Journal*, **1**: 306 and 308 (1903).

(4) DUNN, E. J.: *The Bushmen.* Griffin (1931).

(5) HEESE, C. H. T. D.: "A sub-triangular perforated polished axe-head." This *Journal*, **31**: 517-8, illus. (1934).

(6) PÉRINGUEY, L.: *Annals S.Afr.Mus.*, **8**: 115 (1911).

(7) *British Museum Handbook to the Ethnological Collections*, 1910 edition, p. 131.

(8) ALEXANDER: *An Expedition of Discovery into the Interior of Africa*, **2**: p. 19.

South African Journal of Science, *Vol. XL, pp. 303-322, November, 1943.*

# 'N SOUTPANSBERGSE ZIMBABWE.

## 'n Voorlopige Ondersoek van 'n Bouval op die Plaas Solvent.

Deur
J. B. de Vaal.

*Lesing gehou op 29 Junie, 1943.*

### Inleiding.

Op uitnodiging van een van my skoolseuns, Marthinus du Plessis, het 'n jonger broer en ek 'n bouval op hulle buurman, mnr. P. J. Le Roux, se plaas Solvent gaan ondersoek.

Solvent is in die Soutpansbergse bosveld, aan die westelike oewer van Sandrivier, vyftien myl noord van Waterpoortstasie geleë. Waar die rivier in 'n noord-oostelike rigting swenk is daar feitlik ewewydig met hierdie swenkende gedeelte 'n rant, by die omwonende naturelle as Machemma bekend, met verskeie koppe daarop. Op die middelste een, wat vanuit 'n afstand bo-op plat vertoon, is die bouval wat in die bespreking „Machemma" genoem sal word.

Die kop is bosbegroeid, maar is nie so ruig dat dit nie sonder 'n voetpad van alle kante bestyg kan word nie. Vanaf die oostekant gaan daar in 'n westelike rigting, langs die suidelike hang van die rant, 'n vee- en wildsvoetpad tot byna op die kop.

Vanaf die suidekant bestyg, word die aandag omtrent vyftig treë vanaf die kruin al getrek deur stukke been, kleipotskerwe en as wat met grond vermeng is.

Die bouval is op die afgeplatte maar nie die hoogste punt van die kop geleë nie. 'n Endjie oos is dit effens hoër. Die meeste van die mure is gedeeltelik ingeval, maar staan op sommige plekke nog vyf voet hoog. Die hele bouval beslaan 'n terrein van oos na wes ongeveer 270 voet en van noord na suid ongeveer 180 voet.

Die klippe wat vir die pakwerk gebruik is, is melk- en grys kwartsiet, met 'n gemiddelde grootte van omtrent 9dm. × 3dm. × 2dm. Hierdie klippe is in die omgewing uitgebreek en opgetel. Aan die oostelike en noord-oostelike helling van die kop kom rotslae voor waar 'n mens kan sien dat baie klippe uitgebreek is. In hulle natuurlike reghoekige vorm is hierdie klippe besonder geskik vir boudoeleindes, sodat dressering onnodig was. Die kleinheid van die bouklippe en die geweldige omvang van die bouval, dui op 'n ontsaglike hoeveelheid werk wat verrig is.

Die klippies is opmekaar gepak en geen bindmateriaal is gebruik nie. Aan die buite- en binnekant is die mure ewe netjies afgewerk. In vergelyking met ruwe Bantoeklipmure wat

te Waterpoort, Bushy Rise, Melrose en Naus voorkom, is hierdie pakwerk besonder netjies. Tog is die verband in die mure, soos aan die foto's gesien kan word, betreklik swak. Waar twee mure 'n aansluiting vorm is daar op een plek 'n verband en by 'n ander een is die mure net styf teen mekaar gebou.

Die bouval kan in twee afdelings verdeel word: die oostelike gedeelte wat deur 'n muur ingesluit word wat ruweg sirkelvormig vertoon, en die westelike, wat gedeeltelik ingesluit word deur twee mure met 'n wye opening tussen hulle westelike uiteindes.

'n Paar honderd treë oos van die bouval is daar twee ander koppe waarop, op veel kleiner skaal, pakwerke voorkom. Dis in boustyl verwant aan Machemma, maar is tot op die grond ingeval.

Die mure van die bouval eindig almal met netjiese rondings. Aan sommige dele van die bouwerk is baie meer sorg bestee as aan ander dele. Die suidelike lang muur aan die westekant vanaf G tot by die uiteinde daarvan, wat 8 voet breed en op sommige plekke nog 4 voet hoog is, is gepak met taamlike groot reghoekige klippe. In vergelyking met die pakwerk in die oostelike gedeelte van die bouval, is dit nie netjies nie.

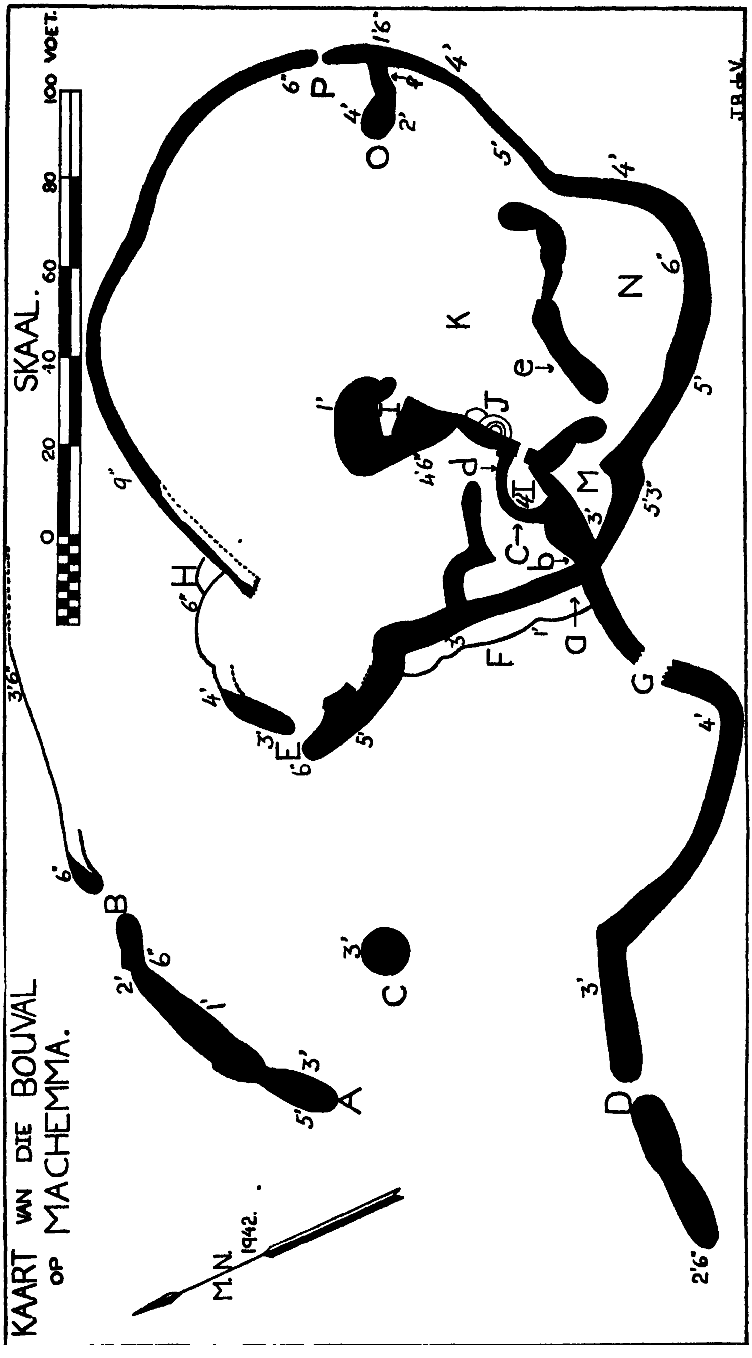
## 'n Bespreking van die Onderdele van die Bouval.

Hier volg 'n bespreking van die onderdele van die bouval soos op die bygaande sketskaart aangedui: (Hoogtes van mure is op die sketskaart bygeskryf).

A is die uiteinde van die lang muur wat in 'n westelike rigting loop. Dit neem 'n platformfiguur met die volgende afmetings aan: Die breedte op die wydste plek is 6 voet 9 duim, en die lengte vanaf die punt tot by die eerste vernouing 18 voet 6 duim. Die grootste hoogte is 5 voet.

B is 'n breek in die bykans ingevalle muur, en was waarskynlik 'n ingang. Vanaf B oostwaarts, tot waar die stippellyn op die sketskaart begin, kan 'n muur gevolg word wat op die hoogste plek 3 voet 6 duim is. Dit was waarskynlik 'n terrasmuur, want die bokant daarvan is met losgrond bedek en onsigbaar.

C is 'n sirkelvormige pakwerk van netjiese klein klippies. 'n Paar jaar gelede was dit, volgens die getuienis van mnr. Evert du Plessis wat op die aangrensende plaas Kortdraai woon, omtrent 8 voet hoog. Toe was daar al van die klippe afgeval. Langs die verhoog het 'n boom aan die oostekant gestaan wat omgewaai het. Dit het die boonste gedeelte daarvan na die westekant toe laat instort. Die hoogte van die gedeelte wat nog staan is 3 voet. Op die bodem is die deursnit 9 voet 4 duim en bo is dit 8 voet 8 duim. Dit word dus na boontoe nouer. Aan hierdie verskynsel geoordeel moes dit 'n keëlvorm gehad het. Dit wil my voorkom of hierdie pakwerk 'n miniatuur van die groot keëlvormige toring van Zimbabwe is.


KAART VAN DIE BOUVAL
OP MACHEMMA.
SKAAL.
0 20 40 60 80 100 VOET.
M.N.
1942.
J.B.d.V.

D is 'n deurgang in die lang muur.

E was waarskynlik die hoofingang. Die mure hier is breed, stewig, maar taamlik ingeval. Beide mure vorm by hulle uiteindes rondings. By die ingang lê 'n swart klip, netjies afgewerk om 'n ovaalvorm met die volgende afmetings aan te neem: 5 voet 2 duim lank, 1 voet in die middel breed, en 4 duim dik. Die gewig daarvan is volgens skatting 250 lbs. Teneinde 'n foto te kan neem moes dit regop getel word.

Hierdie klip is waarskynlik van elders daarheen vervoer, want in die onmiddellike omgewing kom nie sulke klippe voor nie. By die ingang van die murasie op die suid-oostelike kop lê ook 'n buitengewone lang klip, maar dis een uit die omgewing en nie so netjies gedresseer nie.

F, die kronkellyn tussen die twee mure, is 'n terrassie of trap, waarvan die muurtjie met klein klippies gepak is. Die ruimte tussen hierdie muurtjie en die groot muur is opgevul met grond en klippe. Treffend is die netjiese sirkelbogies wat deur die muurtjie beskryf word. Was dit 'n ornament, 'n koninklike sitplek, 'n trap of 'n stut van die hoofmuur?

G is 'n breuk in die lang suidelike muur.

H.—Toe ons besig was om die westelike gedeelte van die noordelike muur vir 'n afstand van 30 voet onder losgrond met troffeltjies oop te krap, het my broer op 'n stukkie pakwerk afgekom wat die vorm van 'n sirkelbogie aanneem en die twee mure verbind. Dit wil my voorkom of dit 'n trappie was, in ooreenstemming met die trappies by Zimbabwe.

J.—'n Eienaardige verskynsel is verskillende terrassies in die vorm van sektors van sirkels teen die muur. Hulle is los daarvan gebou en sluit nie met 'n verband daarby aan nie. Nadat hierdie terrassies blootgelê is deur die ingevalle klippe weg te gooi waardeur hulle bedek was, het hulle van die hoofmuur met omtrent 5 duim weggeskuiwe. Die hoogte vanaf die bodem van die laagste tot die bodem van die hoogste is 2 voet. Die doel hiervan was waarskynlik om as stut teen die muur te dien. Caton-Thompson (1931) het te Zimbabwe in die Maund-bouvalle 'n dergelike verskynsel aangetref.

I, L en M.—Dis vertrekke waarvan die vorm is soos in die tekening aangedui. Die wydte van I by die ingang is 3 voet 6 duim en die diepte 12 voet. Die ruimte binne die vertrek is gedeeltelik met losgrond opgevul. Die mure is op die hoogste plek aan die binnekant 3 voet.

L bestaan uit 'n ruimte ingesluit deur twee mure, een waarvan 'n sirkelboog vorm wat met 'n verband by 'n reguit stuk muur aansluit. Die bouklippe is hier besonder klein. Die half-sirkelvormige muurtjie is smal, n.l. 1½ voet, maar dis baie stewig. Die vertrek is op die breedste plek 8 voet en van voor tot agter 12 voet diep. Aan die agterkant binne is die muur 4 voet hoog. In teenstelling met die ingange van die ander vertrekke eindig die ingangmuurtjies reghoekig. Die wydte van

die ingang is 2 voet 10 duim. Binne in die vertrek is losgrond wat deur iemand uitgegrawe moes gewees het.

M is peervormig. Die mure loop in die westekant met 'n skerphoek na mekaar toe. Die grootste wydte daarvan is 14 voet 6 duim en die diepte 25 voet. Wat die funksie van hierdie vertrekke was kon ek nie by my informante uitvind nie. Dis heeltemal moontlik dat dit as woonvertrekke kon diens gedoen het.

K is die hoogste punt binne die bouval waar die „Dumpey"-toestel opgestel is om die verskillende lesings te neem.

N is 'n afdeling in die bouval wat heeltemal laer as enigeen van die vertrekke I, L en M lê.

O is 'n platform van netjiese reghoekige klippies gepak. Vanaf die punt tot by die eerste vernouing is dit 12 voet lank en op die breedste plek, d.w.s. 5 voet vanaf die westelike punt, 7 voet 3 duim breed. Vanaf die vernouing word die muur met 'n buiging voortgesit. By die hoogste plek is dit 4 voet hoog. Soos aan die sketskaart gesien kan word is dit uit die halfsirkelvormige ringmuur gebou en sluit met 'n verband daarby aan.

Drs. van Hoepen en Hoffman (1935) het in die distrik Zeerust Bahurutsi murasies ondersoek. Daar het hulle dergelike platforms gevind wat volgens hulle sou gedien het om koringbakke of -mandjies op te plaas. Na alle waarskynlikheid het platform O vir dieselfde doel gedien.

P is 'n waarskynlike ingang, baie smal.

Wat treffend van die bouval is, is dat daar soveel losgrond binne in en in die onmiddellike omgewing daarvan voorkom. Die hele noordelike muur vanaf punt P tot naby die ingang E waar dit doodloop, staan nêrens hoër as 9 duim bokant die grond uit nie. Op een plek waar 'n erdvark (?) van die buitekant langs die muur gegrawe het, gaan die pakwerk nog vir omtrent 3 voet in die losgrond af. Al gaandeweg het ek die indruk gekry dat 'n groot gedeelte van die bouval met grond bedek is —toegegooi miskien—en dat opgrawingswerk heelwat nuwe strukture behoort bloot te lê.

### Die Gebruik van Monoliete onder die Bantoes.

By die Zimbabweruïnes het Caton-Thompson (1931) ook lang klippe by die ingange van die bouvalle aangetref. Sy meen dat dit deurkosyne was.

Op die plaas Melrose, waar die murasies van die Sotho-opperhoof Sebola se eertydse stat nog te sien is, is daar bo-op die grootste nog staande muur drie lang klippe ingeplant. Dié klippe kom egter uit die onmiddellike omgewing en is nie netjies afgewerk nie. In dieselfde muur is daar drie ingeboude sitplekke aan dieselfde kant van die muur op 'n ry.

Te Dzata aan die Njelelerivier, waar die ruïnes van die eerste Bawenda-immigrante in Soutpansberg nog staan, is 'n

sirkelvormige platformpie naby, direk noord van die groot ovaalvormige mishoop van die veekraal. Dit het 'n deursnee van 10 voet en is gebou van twee lae ruwe klip. Bo-op is drie hopies klip waarin waarskynlik drie lang klippe ingeplant was. Een daarvan lê nou bo-op plat en twee aan weerskante van die platform. Die lengtes is 3 voet 8½ duim, 3 voet 1 duim en 3 voet 7½ duim respektiewelik.

Stayt (1931) meld in sy monografie dat groepe van die Bawenda heilige bulle besit. Diegene wat arm is hou heilige klippe aan. Gewoonlik word daar twee ingeplant, waarvan die grote die koei en die kleintjie die bul voorstel. Soms vind 'n mens onder die Bawenda en die Karanga drie sulke heilige klippe.

'n Baie interessante opmerking van Stayt (1931) is die volgende: „Another feature of some interest is the occurrence, in different places, of odd stones (plate vi) put up for some undiscovered reason. The shape of these stones suggests that they were of phallic origin, and possibly that the people who erected them were influenced by their contact with Zimbabwe, where so many phallic symbols have been identified. Frequently one or more such monoliths are placed on the wall at a village entrance or in the main yard (plate vii) apparently for no specific reason, but merely in imitation of their ancestors."

Dis dus moontlik dat die monoliet onder bespreking as deurkosyn kon gedien het, of dat dit, in nabootsing van die monoliete wat by Zimbabwe bo-op die mure voorkom, by die ingang as falliese simbool op die muur ingeplant was.

Op die plaas Vasval, omtrent twintig myl suid van Machemma is deur mnr. J. H. Otto 'n keëlvormige falliese klippie opgetel, wat ek in 1933 self gesien het. Hierdie plaas is volgens oorlewering deur Sotho's bewoon.

In my besit het ek 'n baie netjies en eweredig geslypte keëlvormige klippie. Dis 2½ duim hoog en die sirkelvormige bodem het 'n deursnit van 1½ duim. Ook die bodem is glad met 'n effense ronding geslyp. Dis op die plaas Nakab 1121, deur een van my leerlinge, Izak van Rooyen, naby 'n verlate Bawendastat opgetel. Nakab lê 'n paar myl wes van die Njelelerivier in die hartjie van Wendaland. Ons kan dus aanneem dat hierdie klippie aan die Bawenda behoort het en dat dit 'n falliese voorwerp was. Dit dui op 'n verwantskap tussen die Bawenda en die Sotho's van Soutpansberg met Zimbabwe, omdat daar by Zimbabwe verskeie sulke klein falliese voorwerpe deur navorsers gevind is.

## Patrone in die Mure.

Op verskeie plekke in die mure kom daar patrone voor. Dit word met pylpuntjies op die bygaande sketskaart aangedui.

(1) By ◡ is 'n patroon aan die westekant van die noordsuid muur. Dit bestaan uit lae wit klippe afgewissel deur lae grys kwartsiet. Die kleure en die manier waarop die klippe gepak is kan duidelik op foto No. 4 gesien word.

Dieselfde soort patroon is deur prof. Dr. Leo Fouché (1937) in die murasies op die plase Maryland, vyf myl noord van Messina, en Haddon, 19 myl wes van Messina gevind.

Hierdie ,, banded decoration '' kom ook in 'n stuk muur by die keëlvormige toring in Groot-Zimbabwe voor.

(2) By b, in die hoek van twee aansluitende mure het 'n paar skuinsstaande klippe net bokant losgrond wat teen die muur opgehoop was, verdag voorgekom. Nadat hulle verder oopgegrawe is, is 'n pragtige visgraatpatroon blootgelê. Die lengte wat deur die patroon beslaan word is 4 voet 8 duim en die wydte daarvan 1 voet. Die klippe wat gebruik is, is plat grys kwartsiet. (Sien Foto No. 5.)

Visgraatpatrone kom in Soutpansberg in die bekende Murasie op die plaas Verdun voor, omtrent 4 myl wes van Mopanistasie. Ook word dit gevind in die genoemde bouval op die plaas Maryland, en op uitgebreide skaal in verskeie Rhodesiese Zimbabwes, waarvan die te Dhlo-Dhlo en Nanatali van die vernaamstes is.

(3) By c is 'n aantal skuinsliggende klippies in die muur wat 'n ,, girdle ''-patroon voorstel. (Sien Foto No. 6.) Sover bekend kom hierdie patroon in Soutpansberg alleenlik in die bouval te Maryland voor en in Rhodesië, veral te Dhlo-Dhlo en Nanatali.

(4) By e, d en f kom die bekende ,, chessboard ''-patroon voor. Te Verdun is daar twee sulke patrone in die muur en ook in die bouvalle van Dhlo-Dhlo en Nanatali. (Sien Foto No. 7.)

## VERDERE PUNTE VAN OOREENKOMS TUSSEN MACHEMMA EN ANDER BOUVALLE.

Verdun.—Beide Verdun en Machemma is met klippe gepak wat uit die omgewing kom. Geen definitiewe waterpaslyn is gevolg nie, omdat klippe van verskillende diktes gebruik is. In beide bouvalle is klein klippies onder die groteres as wiggies gebruik om die bouklippe in posisie te laat lê. By Verdun eindig een van die mure met 'n ronding soos te Machemma. Te Verdun kom in een muur egter 'n ingeboude sitplek voor. Tot dusver is soiets nie te Machemma gevind nie.

Dzata.—Die muuruiteindes van beide bouvalle te Dzata en Machemma is rond. Hier is ook geen waterpaslyn met die pakkery gevolg nie. Klipwiggies kan oral gesien word. Volgens tradisie is die bouklippe, pragtige plat eweredige skales, uit Rhodesië deur die eerste immigrante aangedra. Hoewel die platform wat te Dzata' voorkom sirkelvormig is netsoos die te Machemma, is daar geen verdere ooreenkoms nie, omdat eersgenoemde van ruwe klip, slegs twee lae hoog gebou is, en laasgenoemde keëlvormig en sowat agt voet hoog sou gewees het. Te Dzata is ingeboude sitplekke in die mure wat ooreenkoms met Verdun vertoon.

Melrose.—Op Melrose vertoon die drie ingeboude sitplekke in die muur ooreenkoms met Dzata en Verdun. Die pakklippe is ru en uit die omgewing opgetel. Dis verreweg nie so netjies as die in die voorgenoemde drie nie.

Die patrone vorm dus 'n skakel tussen Machemma en Verdun; die ingeboude sitplekke 'n skakel tussen Verdun, Dzata en Melrose, en die pakwerk een tussen Verdun, Machemma en Dzata.

## Los Voorwerpe wat te Machemma Gevind is.

Die voorwerpe wat gevind is bestaan uit die volgende:

Van Klei:

(1) Baie kleipotskerwe met verskillende vorms van versiersels daarop.

(2) Sewe heel spoelwieletjies („ spindle whorls '') en ses halwes.

(3) Drie stukkies plat gebakte klei, waarskynlik kleipotskerwe waarvan twee rond en een ovaalvormig geslyp is.

Van Yster:

(4) 'n Skoffelpikkie.

(5) 'n Asgaailem.

(6) 'n Pylpunt sonder weerhaak.

(7) Drie stukkies plat yster waarvan twee na dele van skoffelpikke lyk.

(8) Dele aanmekaargeroeste arm- en beenringe. Die hare van die dierstert waaromheen die draad gedraai was het vergaan met die gevolg dat daar 'n gaatjie gelaat is.

(9) Verskeie stukkies slak, waarskynlik oorblyfsels uit 'n hoogoond waarin metaal gesmelt is.

Van Koper:

(10) 'n Stukkie verroeste koper arm- of beenring, van draad gedraai.

(11) Twee stukkies koperdraad in klein rolletjies opgedraai.

Van Klip:

(12) Verskeie maalklippe, rondes waarmee gevryf is en uitgeholde plattes waarin gemaal is.

(13) Klippe waarop, te oordeel aan die groewe daarop, asgaailemme geslyp is.

(14) Twee stukkies blou geslypte seepsteen.

Been:

(15) Baie stukkies been lê oral rond.

Krale:

(16) Op die ashope het ons opgetel en uitgesif:

  (a) 'n Groot aantal volstruiseierdopkrale van verskillende groottes.

  (b) Verskeie skulpkrale.

  (c) 6 Geel glaskrale.

(d) 4 Groen glaskrale.
(e) 12 Blou glaskrale van verskillende skakerings, t.w., 4 donkerbloues, 2 ligter bloues en 6 heeltemal ligblou.
(f) Een besondere klein swart kraaltjie.
(g) 'n Aantal plat swart krale wat lyk of hulle van klip gemaak is.
(h) 'n Swart kraal, in grootte gelyk aan die bloues. Dit lyk of dit van glas gemaak is.

### Die Betekenis van die Krale.

Vyf van die ligbloues en een van die donkerblou krale wat op Machemma gevind is, is ,, Vhulungu ha Madi '' (krale van die water). Hierdie soort krale word vandag deur die Bawenda wat van koninklike afkoms is as erfstukke gedra, en baie hoog waardeer, omdat dit volgens wyle B. H. Dicke (1936) nie meer in Europa gemaak kan word nie.

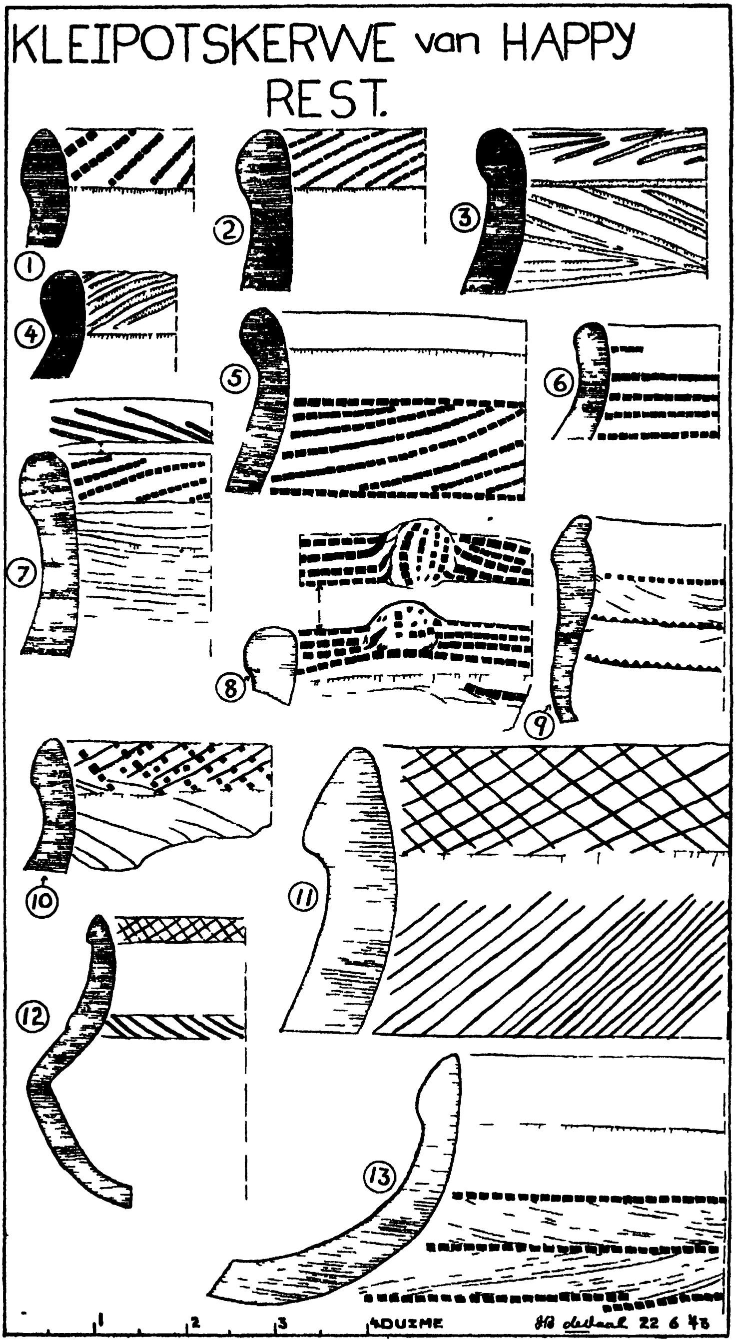
Caton-Thompson (1931) het in die onderste lae van die Zimbabweruïnes ,, Vhulungu ha Madi '' uitgegrawe wat volgens haar meer as duisend jaar gelede daar gelaat is. Dit toon gevolglik kontak tussen die Bawenda, Zimbabwe en die bewoners van Machemma aan.

### Wat Verder uit die Materiële Oorblyfsels van Machemma af te lei is.

Die ras wat op Machemma gewoon het was veebesitters. Die askleurige mis, vermeng met grond wat in die noord-oostelike gedeelte van die bouval voorkom, bewys dit. Hulle was bewerkers van die grond, soos van die heel skoffelpikkie en verskeie pikdele wat daar gevind is, afgelei kan word. Hulle graan, waarskynlik kafferkoring, wat vandag nog deur die Bantoes noord van Soutpansberg verbou word, omdat dit in hierdie droë dele beter as mielies aard, het hulle op maalklippe, wat orals rondlê, gemaal.

Stukkies slak getuig daarvan dat hulle bewerkers van metaal was. Dis bekend dat yster en koper voor die koms van die Voortrekkers in 1836 na Soutpansberg en etlike jare na hulle vestiging hier, deur die Bantoes bewerk is. Die stukke arm- en beenringe, asook glas-, skulp-, klip- en volstruiseierdopkrale dui daarop dat die betrokke ras hulleself versier het. Kleipotte is deur hulle vir huishoudelike doeleindes gebruik. Verder was hulle 'n jagtersgemeenskap, soos van die baie bene wat daar voorkom afgelei kan word. Volgens die ,, spindle whorls '' moes hulle gespin en geweef het.

Die materiële oorblyfsels vertel dus van 'n ras wat hier gewoon het, wie se leefwyse ooreenstem met dié van ons Suid-Afrikaanse Bantoe toe hy nog 'n selfonderhoudende lewe, weg van Europese invloed, gevoer het. Die kleipotskerwe, waarvolgens vasgestel kan word watter ras daar gewoon het, is nog nie deur deskundiges ondersoek nie.


KLEIPOTSKERWE van HAPPY REST.
1
2
3
4
5
6
7
8
9
10
11
12
13
1
2
3
4DUIME
22 6 48

### BANTOE TRADISIE IN VERBAND MET DIE BOUVAL.

Die getuienis van drie ou naturelle, nl. Swartbooi, Lishivha en Molikoa Dôdza, wat op die plase Mollevel, Matjiesvlei en Albert respektiewelik woon, is ingewin. Hierdie plase lê almal binne twintig myl van Machemma af. Die informante het in die omgewing opgegroei, sodat hulle vertellinge as die juiste tradisie aangeneem kan word.

Aldrie is dit eens dat Machemma baie lank gelede deur 'n Sotho-opperhoof Sebola bewoon is. Hy het by die berg Tswime naby Dzata aan die Njelelerivier saam met een van die Bawenda-grootkapteins Thoho-ya-Ndou of Ramapulana gewoon. As gevolg van rusie met die Bawenda het hy gevlug en hom te Machemma gevestig. Teneinde teen die Bawenda beskerm te wees het hy die klipmure daar laat bou.

Te Machemma is yster gesmelt, waarvan die erts van 'n plek naby Sibasa gebring is. Die sirkelvormige verhoog is deur die kaptein gebruik om op te sit.

Sebola is van Machemma deur die Bawenda verjaag en het verskeie plekke in die distrik bewoon. Hy en sy seun Tôpôro lê langsmekaar op die plaas Melrose aan die noordelike voet van Soutpansberg begrawe. Sy kleinseun Petrus woon omtrent vier myl daarvandaan op Matjiesvlei, en is 'n indoena, ondergeskik aan die Bawenda grootkaptein, Mphefu.

Petrus Sebola is volgens homself en Dr. N. J. van Warmelo (1935) 'n Mosotho. Volgens 'n mededeling van mnr. Jannie Otto wat tshiVenda vlot kan praat, en op wie se plaas Petrus woon, praat die huidige Sebola se moeder nog tshiVenda. Onder mekaar het ek sy raadsmanne ook tshiVenda hoor praat. Hierdie Sothos is gevolglik onder sterk Wenda-invloed, en ons kan aanneem dat dit ook die geval met die bewoner van Machemma was, omdat hy by die Bawenda aan die Njelelerivier opgegroei het. Soos reeds aangetoon verraai die „ Vhulungu ha Madi " ook kontakte met die Bawenda of met die bron vanwaar die krale oorspronklik kom.

### SAMEVATTING.

Uit die voorgaande blyk dat die bouval op Machemma Zimbabwekultuur is. Met Groot-Zimbabwe het dit die Keëlvormige toring, die rondings waarmee die mure eindig, die patroon van afwisselende lae swart en wit klippe, die monoliet, die spoelwieletjies en die halfsirkelvormige trappies en terrassies gemeenskaplik. Dis in Soutpansberg verwant aan die bouvalle te Verdun, Maryland en Haddon, wat die pakwerk en die patrone in die mure betref. Met Dzata het dit die pakwerk en rondings waarmee die mure eindig gemeenskaplik. Aan Nanatali en Dhlo-Dhlo is dit in verskeie opsigte verwant, die vernaamste waarvan is die visgraat-, „ chessboard-" en „ girdle-"patrone. Dhlo-Dhlo en Nanatali vorm weer 'n direkte skakel met Zimbabwe omdat hulle verskeie punte van ooreenskoms vertoon, o.a. die chevronpatroon.

Hierdie resultaat lei ons tot 'n volgende vraag: In welke verband staan die Sotho- en Wendavolk tot Zimbabwe?

## DIE SOTHOS.

Volgens J. F. Schofield (1937) is Zimbabwe vanaf 'n onbekende tydperk tot ± 1450 deur Sothos bewoon, en vanaf ± 1500 tot ± 1825 deur Shonas wat in kontak met die Rozwi-Wendavolke geleef het. Verder het hy aangetoon dat hierdie Sothos wat by Zimbabwe gewoon het in ± 1450 suidwaarts oor die Limpopo getrek het en hulle waarskynlik te Mapungubwe gevestig het, want daar het hy ook Sothokultuur, wat Zimbabwe-kultuur verraai, aangetref. Of Machemma deur lede van dieselfde groep of veel later bewoon is, sal nog deur opgrawingswerk aangetoon moet word. In ± 1500 trek 'n deel van die Shonastam oor die Limpopo en lewe saam met die Sothos van Mapungubwe. Na die werk van verskillende deskundiges kon prof. Fouché (1937) in sy samevatting van die oorblyfsels te Mapungubwe sê: .... „The culture revealed at Mapungubwe is closely related to that of Zimbabwe. It is 'Bantu,' in the loose sense in which that term has been used hitherto."

Volgens Dr. Galloway (1937) is die skedels egter nie dié van Bantoes nie, maar van 'n veel ouer ras, nl. Bush-Boskop.

Kaptein Gardner (1942), onder wie se leiding die opgrawingswerk geskied het tot met die uitbreek van die oorlog in 1939, het die volgende aan die lig gebring: Die koppie Bambandyanalo of K2, wat omtrent 'n driekwartmyl suid-wes van Mapungubwe lê, is lank voor die koms van die suidwaarts bewegende Bantoehordes deur Hottentotte bewoon. 'n Deel van die bewoners van K2 het nie vir die Bantoes gevlug nie, maar het hulle onderwerp en met die veroweraars ondertrou. Gevolglik is die skedels wat op beide koppies gevind is die van Hottentotte wat met Bantoes verbaster het.

Dr. van Hoepen (1939) het in die Lydenburgse distrik bouvalle ondersoek wat sekere kenmerke met Zimbabwe gemeen het en wat volgens hom deur die Bapedi gebou is. Dit bring hom tot die gevolgtrekking:—„ At all events Zimbabwe then represents the climax of the Bantu stone building culture of which it was the highest developed centre."

As gevolg van die Hottentotagtige geraamtes van Mapungubwe, en die Zimbabwekultuur wat daar aangetref word, sê Dr. van Hoepen: „ We can only conclude, that the Zimbabwe type of structure was originally built by a Hottentot race or a race of Hottentot descent. It was apparently from this race that the South African Bantu (Negro) took over the method of building with stone."

As die Hottentotte die oorspronklike bouers van die Zimbabwestruktuur was, sou 'n mens by hulle woonplekke, voordat hulle in kontak met die Bantoe gekom het, sulke bouwerke verwag. Te Mapungubwe is die mure egter van ruwe klip wat in geen opsig verwantskap met Zimbabwe vertoon nie.

Die Zimbabwekultuur wat daar aangetref is, is volgens Schofield daarheen deur Bantoes gebring, t.w. Sothos, maar het hom nie in boustyl ontplooi nie. Dis dus baie onwaarskynlik dat die Hottentotte die leermeesters van die Bantoe kon gewees het.

Dr. Hoffman (1942) merk i.v.m. hierdie teorie, nl., dat die Hottentotte die leermeesters van die Bantoe sou gewees het, die volgende op: ,, . . . .van wat ek persoonlik van die bouwerke " (die Zimbabweruïnes in Suid-Rhodesië) ,, gesien het, is dit uiters moeilik om uit te maak dat twee sulke uiteenlopende rasse " (nl., die Hottentotte en die Bantoes) ,, daaraan kon gebou het. Veral wat Groot-Zimbabwe betref, is daar aan die klipmure heelseker geen twee of drie kulture uit te maak nie. My opinie is dat die Bantoes Groot-Zimbabwe gebou het en dat hulle alleen daarvoor verantwoordelik gehou moet word."

Kaptein Gardner (1942) beskou die Zimbabwes ook as ,,. . . .the highest achievements of the Bantu people who had perhaps cultural contact with east coast Arabs." Hierdie veronderstelling dat die bouers van Zimbabwe onder Arabiese invloed gestaan het, word aan die einde van die artikel weer in verband gebring met die Balemba, die ambagsmanne onder die Bawenda. Laat ons nou eers nagaan welke kontakte die Bawenda met Zimbabwe gehad het.

## DIE BAWENDA.

Volgens Schofield (1937) was die Bawenda saam met die Rozwi in noue voeling met die Shonas wat Zimbabwe bewoon het. Soos reeds aangehaal meen Stayt (1931) dat die monoliete wat die Bawenda op die mure by die ingange van hulle statte inplant, falliese klippe is, in nabootsing van die wat te Zimbabwe gevind word. Ook die keëlvormige klippie op die plaas Nakab in Wendaland opgetel, vertoon ooreenkoms met die falliese voorwerpies wat te Zimbabwe gevind is. Caton-Thompson (1931) het te Zimbabwe dobbelsteentjies uitgegrawe wat net soos dié lyk wat deur Bawenda-dolosgooiers gebruik word. Dit lei Stayt tot die gevolgtrekking: ,, I am inclined to believe that the use of the dice has originated in the Zimbabwe area and is associated with the old Zimbabwe culture." Ook sien hy 'n ooreenkoms tussen die Bawenda toorbakkie (,, divining bowl "), wat binne in met houtsneewerk versier is, en die versierde bak wat deur Bent in 'n grot, tien myl van Zimbabwe af, gevind is.

Volgens Stayt stem die tegniek waarvolgens die Wendabouvalle van Dzata gebou is, baie ooreen met die van Zimbabwe.

Op die ,, Vhaulungu ha Madi " wat onder die Bawenda voorkom en wat ook deur Caton-Thompson te Zimbabwe gevind is, is al gewys.

Na analogie van die voorgaande is ons geregverdig om aan te neem dat die voorvaders van die Sotho-Wendavolke van Soutpansberg die bewoners van Zimbabwe was. Maar, was hulle ook die bouers?

Met haar opgrawingswerk te Zimbabwe het mej. Caton-Thompson 'n baie interessante verskynsel teëgekom. In laag 2, onder die sementvloer en gelyk met die fondamente van die mure het sy 'n groot hoeveelheid kleipotskerwe uitgegrawe wat deur haar klas-A genoem word. Sy is die sienswyse toegedaan dat dit daar voor of tydens die bouperiode van die mure gelaat is, en dat dit van kleipotte afkomstig is wat aan die bouers van Zimbabwe behoort het. Sy beskryf dit as volg: „. . . .a coarse redbrown to dark grey handmade ware, gritty with quartz particles and badly fired: the rims have a flat overturned lip . . . .and they are sometimes decorated with diagonal or other arrangements of shallow square or round impressions in the wet clay."

Bo-op die sementvloer het sy ander soort skerwe gevind wat sy klas-B noem. Dis van 'n fyner en beter gehalte as klas-A. Dit laat haar die gevolgtrekking maak dat die bouers van Zimbabwe nie die bewoners was nie. Omdat klas-A van 'n swakker gehalte is, sou die bouers die slawe van die bewonende stam gewees het.

Schofield (1942) meen dat hierdie soort kleipotte gemaak is deur die pre-Sotho bewoners van suidelike Rhodesië. Wells (1935) het in verband daarmee aangetoon dat „except that its decorative techniques are similar to those later employed on Bantu pottery, class A has no distinctively Bantu features . . . . on the other hand, class A pottery has no direct affinities with Hottentot pottery. Its origin remains at present obscure." Volgens Caton-Thompson moes die wat te Zimbabwe gevind is tussen die 8e en 11e eeue gemaak gewees het.

Kleipotskerwe wat onlangs met die aanbou van nuwe klaskamers op die skoolgronde van Happy Rest skoolplaas aan die suidelike voet van Soutpansberg in Wendaland uitgegrawe is, werp lig op hierdie probleem. 'n Groot aantal daarvan het dieselfde versiersels op as die klas-A skerwe van Caton-Thompson en die van die rotsskuilings te Gokomere 10 myl noord van Fort Victoria, wat deur Wells en Schofield (1940) beskryf is. (Vergelyk bygaande tekeninge van 'n paar met dié van Gokomere en Zimbabwe). 'n Mens twyfel nie daaraan nie, dat almal deur dieselfde ras gemaak is, miskien in verskillende tydperke.

Volgens Bantoe-oorlewering was op die terrein waar die skoolgeboue staan baie lank gelede 'n Bawendastat onder die hoofman Matokoma. Ons het dus hier met Wendakleipotte te doen. Kleipotte onder die Bawenda word egter vandag hoofsaaklik deur die vroue van die Balemba gemaak. Daarom is Wendapotte, soos deur Schofield (1942) ook aangetoon, eintlik Lembawerk.

Die Balemba is Bantoes met Semitiese gewoontes en gelaatstrekke, wat volgens Junod (1908), Stayt (1931) en Van Warmelo (1935) met Arabiere verbaster is. Hulle woon in aparte statte sonder 'n eie opperhoof oral tussen die Bantoestamme vanaf die Sambesie tot in die Pietersburgse distrik.

Volgens Junod (1908) het die Balemba die kuns van metaalbewerking en pottebakkery onder die verskillende stamme waar hulle gaan woon het, 'n groot stoot vorentoe gegee. Volgens verskillende Wenda-informante het die Balemba die pottebakkerskuns en die kuns van metaalbewerking, hoofsaaklik koper en yster, onder die Bawenda ingevoer, en aan hulle geleer.

Stukke slak lê oral op die skoolgronde van Happy Rest rond, en 20 treë van die plek af waar die klas-A skerwe uitgegrawe is, het ek langs die watervoor 'n beskadigde smeltoond oopgegrawe. Daaruit is 'n stuk silindervormige blaaspyp van 11 duim lengte en baie stukke slak gehaal. Dit dui op die teenwoordigheid van Lembasmede of Lembainvloed onder die Bawenda van Happy Rest. Volgens Dr. Van Warmelo is daar in die distrik Victoria naby Gokomere ook 'n kolonie Balemba.

Dis dus hoogswaarskynlik dat die Balemba die vervaardigers van die kleipotte is, waarvan die klas-A skerwe aan die voet van Soutpansberg, te Gokomere en by Zimbabwe uitgegrawe is. As dit so is dan was hulle, die ambagsmanne onder die Bantoes, die s.g. slawe van Caton-Thompson, ook die bouers van Zimbabwe.

Maar hulle was dan die meester-pottebakkers onder die Bawenda. Hoe verklaar ons die swak gehalte van die skerwe by Zimbabwe? Dit kan aan swak klei, verwering weens oudheid en nie aan swak tegniek toegeskrywe word nie. 'n Aantal van die klas-A skerwe van Happy Rest is sterk en andere wat diep onder die grond uitkom, meer verweer.

As gevolg van die verwantskap met Groot-Zimbabwe kan ons aanneem dat Machemma en al die ander in-boustyl-verwante bouvalle in Rhodesië ook deur die Balemba vir die bewonende Bantoestamme gebou is, en dat Arabiese invloed, wat deur kaptein Gardner en andere veronderstel word, in die Balemba gesoek moet word.

DANKBETUIGING.

Graag wil die skrywer vir prof. van Riet Lowe en mnr. B. D. Malan van die Argeologiese Buro bedank vir hulle voortdurende hulp d.m.v. briewe en pamflette, en vir prof. Fouché en prof. C. J. Uys vir hulle opregte belangstelling.

REFERENCES.

(1) CATON-THOMPSON, G.: "The Zimbabwe Culture." Clarendon Press, Oxford (1931).

(2) DICKE, B. H.: "The Bush Speaks." Shuter & Shooter, Pietermaritzburg (1936).

(3) FOUCHE, PROF. LEO.: "Mapungubwe." University Press, Cambridge (1937).

(4) GARDNER, CAPT. G. A.: *The Friend*, Bloemfontein. (Aug. 27 1942).

(5) HOFFMAN, DR. A. C.: "Suid-Afrika voor die koms van die Witman." In *Die Volk* (11 Sept. 1942).

(6) JUNOD, H. A.: "The Balemba of the Zoutpansberg." *Folklore* (1908).

(7) SCHOFIELD, J. F.: "A Preliminary Study of the Pottery of the Bantu tribes of South Africa." *This Journal*, 39: 256-281.

(8) STAYT, H. A.: "Notes on the Balemba." *RoyalAnthrop.Inst.Journ.* (1931).

— "The Ba Venda." Oxford University Press (1931).

(9) VAN HOEPEN, IR. en HOFFMAN, A. C.: "Die oorblyfsels van Buispoort en Braklaagte Noordwes van Zeerust." *Argeologiese Navorsing van die Nasionale Museum*, Bloemfontein (1935).

(10) VAN HOEPEN, IR.: "A Pre-European Bantu Culture in the Lydenburg district." *Arg.Navors.v.d.Nas.Mus.*, Bloemfontein (1939).

(11) VAN WARMELO, N. J.: "A preliminary survey of the Bantu tribes of South Africa." Die Staatsdrukker, Pretoria (1935).

(12) WELLS, L. H. SCHOFIELD, J. F. and GARDNER, T.: "The Recent Archaelogy of Gokomere, Southern Rhodesia." *Trans.Roy.Soc.of S.Afr.* (1940).

(13) WELLS, L. H.: "Ceramics in South Africa." Anais da Faculdade de Ciências do Porto (1935).

## PORTRETTE.

No. 1.—Die waarskynlike hoofingang vanaf die westekant geneem, met die regopstaande monoliet in die middel.

No. 2.—Die oostelike Platform O vanaf die westekant geneem.

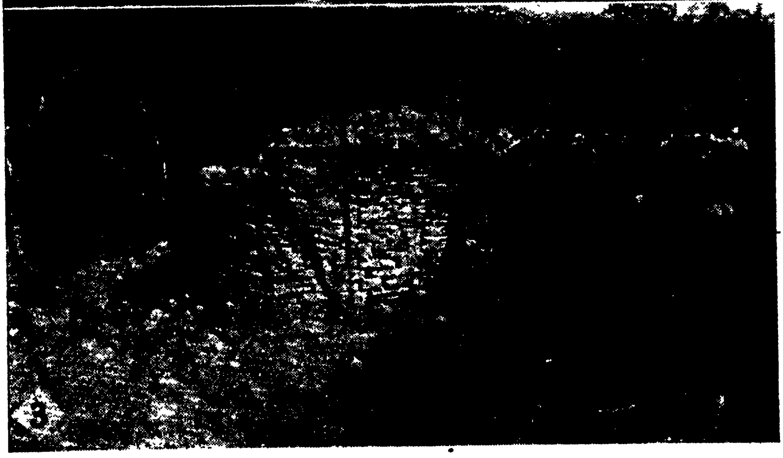
No. 3.—Die Keëlvormige torinkie vanaf die suidekant geneem.

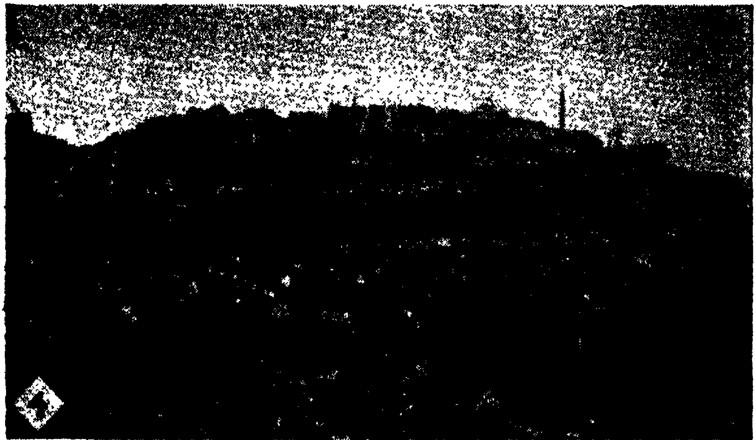
No. 4.—Lae afwisselende swart en wit klippe in die westelike muur by a. 'n Dergelike patroon kom by Zimbabwe ook voor. Op die voorgrond is die muurtjie van die terrassie F herkenbaar.

No. 5.—Die visgraatpatroon by b wat gedeeltelik met losgrond bedek was.

No. 6.—'n "Girdle"—patroon by c. Die paar skuinsliggende klippies vorm die patroon.

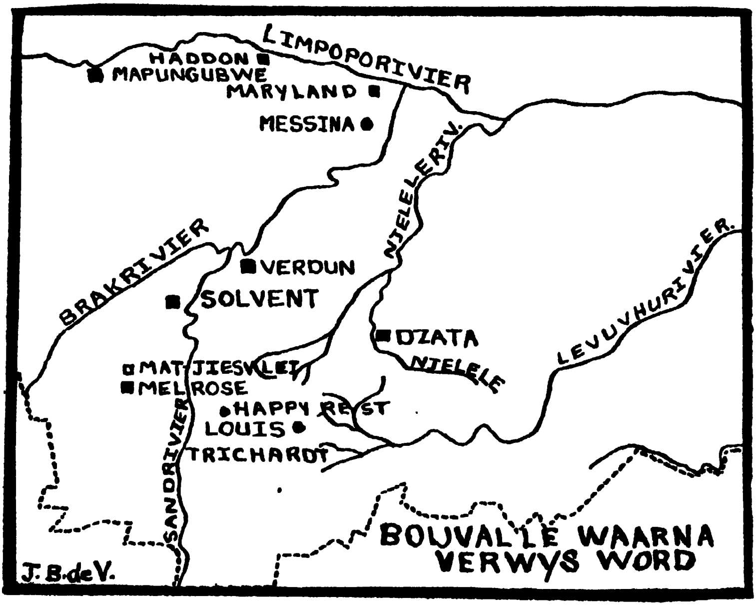
No. 7.—'n "Chessboard"—patroon by e aan die suidekant binne die sirkelvormige muur.






5


7


LIMPOPORIVIER
HADDON
MAPUNGUBWE
MARYLAND
MESSINA
NJELELERIV.
BRAKRIVIER
VERDUN
SOLVENT
DZATA
NJELELE
LEVUVHURIVIER.
MATJIESVLEI
MELROSE
HAPPY REST
LOUIS TRICHARDT
SANDRIVIER
BOUVALLE WAARNA VERWYS WORD
J. B. de V.

## OPSOMMING VAN VERGELYKINGS IN TABELVORM.

| | Machemma | Zimbabwe | Verdun | Dzata | Maryland | Haddon | Melrose | Dhlo-Dhlo | Nanatali | Gokomere | Happy Rest | Die Bawenda | Zeerust | Vasval, 153 | Nakab, 1121 | Mapungubwe | Riet, 1129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Muurpatrone: "Banded" | X | X | | | X | X | | | | | | | | | | | |
| "Chess Board" | X | | X | | | | | X | X | | | | | | | | |
| "Girdle" ... | X | | | | X | | | X | X | | | | | | | | |
| Visgraat ... | X | | X | | X | | | X | X | | | | | | | | |
| Keëlvormige Torings | X | X | | | | | | | | | | | | | | | |
| Ronde Muureindes | X | X | X | X | | | | | | | | | | | | | |
| Monoliete ... | X | X | | X | | | X | | | | | | | | | | |
| Keelvormige falliese klippies | | X | | | | | | | | | | | | X | X | | |
| Ingeboude sitplekke | | | X | X | | | X | | | | | | | | | | |
| Vhulungu ha Madi | X | X | | | | | | | | | | X | | | | | |
| Klas A kleipot-skerwe | | X | | | | | | | | X | X | | | | | | |
| Terrasse en trappies | X | X | | | | | | | | | | | | | | | |
| Spoelwieletjies ("Spindle Whorls") | X | | | | | | | X | | | | | | | | X | X |
| Platforms .. | X | | | | | | | | | | | | X | | | | |

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 323-327, November, 1943.*

# BANTOE LANDBOUTERRASSE NOORD EN SUID VAN BLOUBERG

DEUR

J. B. DE VAAL.

*Gelees 29ste Junie 1943.*

Op die plase Glenferness, The Glen en Witstein, wat direk noord van Blouberg langs mekaar van oos na wes strek, het ek met twee verskillende geleenthede terrasse ondersoek. Mnr. P. C. Potgieter van Kalkoven het die op Glenferness in 1941 aan my gaan wys en Mnr. T. J. Vorster van Goedgedacht was vanjaar saam met my na The Glen en Witstein. Vorster is egter die ontdekker daarvan en sy vriend Potgieter was net met 'n vorige geleentheid saam met hom by die op Glenferness.

Die terrasse op Glenferness kom voor op 'n uitloper van Blouberg, 'n beboste klipperige randjie wat van noord na suid strek. Klippe van die omgewing is langs die hoogtelyne van die heuwel aan die westelike helling in twee rye, vanaf twee tot vier voet ewewydig aan mekaar gepak. Die tussenruimte is met los klippies opgevul, sodat min of meer parallelle muurtjies gevorm is. Slegs op een plek het ek twee gesien wat geleidelik na mekaar toe loop en uiteindelik by mekaar aansluit. Op 'n ander plek is daar twee dwars muurtjies wat twee van die langes reghoekig verbind. Net 'n enkele laag klippe steek by iedere muurtjie omtrent ses duim bokant die grondoppervlakte uit.

Omdat die muurtjies op sommige plekke toegespoel is, en omdat die terrein dig begroei is met bome, is dit moeilik om dit oor 'n hele afstand met die oog te volg teneinde 'n geheelindruk van die omvang daarvan te vorm. Ek het een daarvan vir sowat honderd-en-vyftig treë gevolg tot waar dit wegraak.

Daar is vier-en-veertig opeenvolgende muurtjies getel. Maar dis nie oordrewe om te sê dat daar omtrent 'n honderd voorkom nie. Ons het die afstand tussen sewe-en-twintig vanaf die middel na boontoe gemeet, waarvan die volgende die afmetings is: 15vt. 11vt. 5dm., 11vt. 2dm., 11vt. 8dm., 17vt., 14vt. 6dm., 9vt. 10vt. 9dm., 12vt., 7vt. 7dm., 9vt. 1dm., 11vt. 4dm., 11vt. 11dm. 7vt. 11dm., 11vt. 2dm., 8vt., 8vt. 4dm., 8vt. 10dm., 9vt. 18vt. 3dm., 18vt. 3dm., 17vt. 5dm., 12vt. 10 dm., 15vt. 9dm. 15vt. 8dm., 12vt. 9dm.. 18vt. 2dm. Die dikte van die muurtjies is bygetel.

Oor 'n totale afstand van 109 jaarts 2 voet 4 duim, kom daar dus 27 terrasmuurtjies voor. Hoërop in die heuwel kom

daar nog voor, sodat ons dit, met gebroke tussenruimtes oor 'n breedte van sowat agthonderd treë vanaf die voet verspreid gevind het.

Op party plekke, suid van die muurtjies in dieselfde lyn daarmee, is daar sirkelvormige muurtjies wat ook net uit een laag klippe bestaan. Die grootte van die aldus gevormde sirkel is omtrent dié van 'n naturellehut. Op verskeie plekke teen die randjie kom ronde gate, wat gedeeltelik toegeval het, in die grond voor. In sommige staan bome wat sekerlik al baie oud is.

Wes van hierdie randjie, ewewydig daarmee en geskei deur 'n vlei, is 'n ander een op The Glen, waarop daar ook terrasse voorkom. Die muurtjies is in die meeste gevalle ook net een klip hoog. Baie daarvan is toegespoel of -gewaai. Ook hier kom verskeie ronde gate voor wat gedeeltelik toegeval is.

Vier myl verder wes, op die plaas Witstein, is daar oor 'n afstand van omtrent 'n myl en 'n half aan die voet van die berg honderde terrasse. Met uitsondering van 'n paar wat bymekaar aansluit, is almal min of meer ewewydig. Ook is daar op verskeie plekke dwars muurtjies wat van die terrasse verdeel.

Die lengtes van twee muurtjies is 50 en 75 treë respektiewelik. Dit beteken egter nie dat slegs sulke breë stroke teen die berg uit-geterrasseer was nie. Die muurlengtes breek af en 'n endjie verder ontdek 'n mens tussen die gras, struike en bome weer 'n ander een. In teenstelling met die voriges is party van hierdie terrasmuurtjies met verskillende lae klip tot twee voet hoog gepak. Dis tussen een en drie voet breed.

Op plekke waar baie klippe in die omgewing voorkom is die muurtjies naby mekaar, maar waar minder klippe is, is hulle verder weg. Die afstande tussen 22 opeenvolgendes is as volg: 25, 21, 24, 26, 30, 27, 22, 21, 18, 19, 32, 40, 14, 21, 22, 62, 38, 65, 42, 16 en 17 voet.

Op hierdie plek waar die afmetings gedoen is het ons langs een van die muurtjies 'n uitgeholde gladgeskuurde Bantoe-maalklip gevind, en 'n klein endjie daarvandaan 'n vryfklip en 'n paar stukkies kleipotskerwe sonder versiersels daarop. Aan die geaardheid van die omgewing en die opgetelde voorwerpe geoordeel, lyk dit of daar 'n Bantoestat was. Geen moete van hutte of mishope van veekrale kon egter gevind word nie.

Mnr. Vorster het aan my meegedeel dat hy verder wes op 'n ander plaas ook eenkeer baie terrasse gesien het. Ongelukkig het die tyd ons nie toegelaat om daaraan ook 'n besoek te bring nie. Hoewel ondersoek slegs op drie plekke ingestel is, kom die terrasse volgens die ontdekker feitlik onafgebroke vir myle teen die berg voor.

Ook aan die suidelike en suid-westelike kant van Blouberg word dit aangetref. Mnr. J. H. Cloete, 'n prokureur op Clocolan, O.V.S., wat suid van Blouberg grond besit (en iedere

wintervakansie daarheen gaan), het aan my die volgende interessante mededeling gemaak: „Die terrasse kom baie voor op die plase The Park en Leipzig, suid aan Blouberg en aan die noordekant waar ek 'n ou kaffer in Desember, 1923, nog self gesien werk het in sy armoedige terraslandjie, op die plaas Varedig meen ek. Ek het oor die berg na Leipzig geloop en die honderde terrasse tot hoog op die berg gesien.''

'n Ou kaffer wat noord van Blouberg woon, het aan mnr. Vorster meegedeel dat al daardie terrassies baie lank gelede deur hulle voorvaders, wat daar in die berg gewoon het, gemaak is. Hulle het daarin gepik en gesaai. Om beskerm te wees teen vyande het hulle in 'n tydperk toe Bantoestrooptogte aan die orde van die dag was, so ver as moontlik in die berg gewoon. Teneinde hulle lande te beskerm, waarvan hulle bestaan afgehang het, moes dit naby hulle wees. Hy vertel ook dat hulle lande beter beveilig was teen groot troppe olifante wat die vlakte bo die bergwêreld verkies het.

Volgens die mededeling van die ou naturel, die voorwerpe wat by die terrasse opgetel is, en van wat mnr. Cloete self gesien het, het ons hier met Bantoewerk te doen.

Hierdie terrasse word nie meer gebruik nie. Dis baie ruig begroei en skep alleenlik die indruk dat die meeste daarvan baie lank gelede in onbruik geraak het. 'n Paar myl daarvandaan, die vrugbaarder turfagtige vlakte in, is daar kafferstatte en lande.

Dit moes 'n groot Bantoebevolking gewees het wat daar gewoon het, want die hoeveelheid werk wat met die pak van die terrasse deur mensehande gedoen is, is ontsettend. Die stryd om te bestaan het dit egter noodsaaklik gemaak.

Malaboch, die kaptein van die baXanwana het sy hoofstat op die westelike punt van Blouberg. Onder sy gesag val daar ook nog die maTêbêlê, die baTlôkwa, baTau en baBirwa. Volgens Dr. van Warmelo (1935) vertoon die baTlôkwa verwantskap met die Bawenda, veral wat hulle taal betref. Die baXanwana weer is volgens tradisie van Tswana oorsprong.

Volgens oorlewering is die terrasse noord en suid van Blouberg dus vir landboudoeleindes in 'n pre-Europese tydperk deur Bantoes gemaak, waarskynlik deur een van die stamme onder Malaboch, wat vandag nog daar naby woon.

### Ander Plekke in Suidelike Afrika Waar Terrasse Voorkom.

Volgens Randall-McIver (1906) kom daar in die Inyangadistrik in Suid-Rhodesië teen die heuwels ook uitgebreide klipmuurtjies voor, wat deur hom „the vastest series of entrenchment lines to be found anywhere in the world,'' genoem word. Drs. van Hoepen (1939) en Frobenius (1931) het aangetoon dat dit niks anders as landbouterrasse was nie. Die grond tussen die mure het net met verloop van jare weggespoel. Die Bloubergterrasse staaf hierdie bevinding en vorm met dié van Inyanga in omvang 'n parallel.

Dr. van Hoepen (1939) het in die Lydenburgse distrik ook terrasse gevind, wat vogens hom deur die voorvaders van die Bapedi gemaak moes gewees het.

Daar dien egter op gewys te word dat daar terrasse in Soutpansberg is wat vir woondoeleindes gebruik is en nog gebruik word.

Die Bawenda-opperhoof, Katse-Katse, wat vir die verwoesting van die Voortrekkerdorp Schoemansdal (1848-1867) verantwoordelik was, het hoog teen Soutpansberg aan die voet van loodregte kranse gewoon, 'n klein endjie bokant die skoolgeboue van Happy Rest skoolplaas. Die berg is hier so steil dat terrasse noodgedwonge gebou moes word, teneinde 'n gelyke staanplek vir die hutte te kry. Die moete van hutte is vandag nog daar te sien. Op een plek is daar vier opeenvolgende terrasse. Die laaste een eindig teen 'n krans. Die afsonderlike terrasse is van mekaar afgesluit deur klipmuurtjies van omtrent vier voet hoogte. Kleipotskerwe lê oral rond.

Pater Joaquimi de Santa Rita Montanha, 'n Portugese priester en afgevaardigde van Inhambane na Schoemansdal, het die reis in 1855 te voet afgelê. Dit word deur Joseph Macqueen (1862) in 'n verkorte weergawe van die oorspronklike reisverhaal van de Montanha beskryf. Toe hulle oor die Taverivier gaan, het die geselskap in 'n staat Fera gekom: ,,In Fera they found a large town built on a mountain, the dwellings in rows or terraces rising one above the other.'' Fera word deur Macqueen op 'n sketskaartjie aangegee as 'n berg suid van die Limpoporivier en noord-oos van Schoemansdal. Die Afrikaanse vertaling van de Montanha se oorspronklike reisverslag (1855) lui as volg: ,,. . . 'n Bietjie verder het ons by die kraal van kaptein Mucia Fera gekom, styf teen 'n koppie of berg, 'n groot kafferdorp met baie volk te oordeel aan die baie strooihuise op die kant van die koppie die een bo die ander teen die berg.'' Dit is dus volgens die Afrikaanse vertaling nie duidelik of die heuwel geterrasseer was nie.

Die teenswoordige Bawenda-opperhoof, Mashau, wat teen Mashaukop woon, se hutte staan ook op terrasse.

Volgens van Hoepen (1939) maak Schwellnus melding van terrasse teen heuwels langs die Selatirivier, en Frobenius (1931) vermeld terrasse en ou watervore wat hy op verskeie plase in Soutpansberg gevind het. Hy sê egter nie waar dat die terrasse is nie.

Dis duidelik dat terrasse deur die Bantoes vir woonsowel as landboudoeleindes gebruik is. Vir eersgenoemde doel was hulle natuurlik baie kleiner.

Hierdie drie groepe landbouterrasse, t.w., die te Blouberg, Inyanga en Lydenburg dui 'n kultuurverwantskap tussen die makers daarvan aan. Die bouers van die Lydenburgse en Bloubergse terrasse is Bantoes, gevolglik is ons geregverdig om aan te neem dat die te Inyanga ook Bantoewerk is.

## REFERENCES.

(1) De Vaal, J. B.: " 'n Geterrasseerde Heuwel Noord van Blouberg." *Tydskrif vir Wetenskap en Kuns,* Bloemfontein: Bd. 3, eerste aflewering (1942).

Hierdie artikel is geskryf voordat ondersoek op die plase The Glen en Witstein ingestel is. Dit was toe ook nog nie seker wie die makers van die beskrewe terrasse was nie.

(2) Frobenius, Leo: Erythräa. Atlantis-Verlag, Berlin (1931).

(3) Macqueen, James: "A Journey from Inhambane to Zoutpansberg." *Journal of the Royal Geographical Society* (1862).

(4) Montanha, Pater Joaquim de Santa Rita: Reisverslag na Soutpansberg. Staatsargief, Pretoria: Skenking No. 81 (1855).

(5) Randall-MacIver, D.: "Mediaeval Rhodesia." London (1906).

(6) Van Hoepen, Dr. E. C. N.: "A Pre-European Bantu Culture in the Lydenburg District." *Arg.Nav.Nas.Mus.,* Bloemfontein (1939).

(7) Van Warmelo, Dr. N. J.: "A Preliminary Survey of the Bantu Tribes of South Africa." Pretoria (1935).

South African Journal of Science, *Vol. XL, pp. 328-329, November, 1943.*

# MASARWA ENGRAVED EGG-SHELL
## (In the Collection of the F. S. Malan Museum, Fort Hare.)

BY

Dr. A. J. D. Meiring,
*Hon. Curator.*

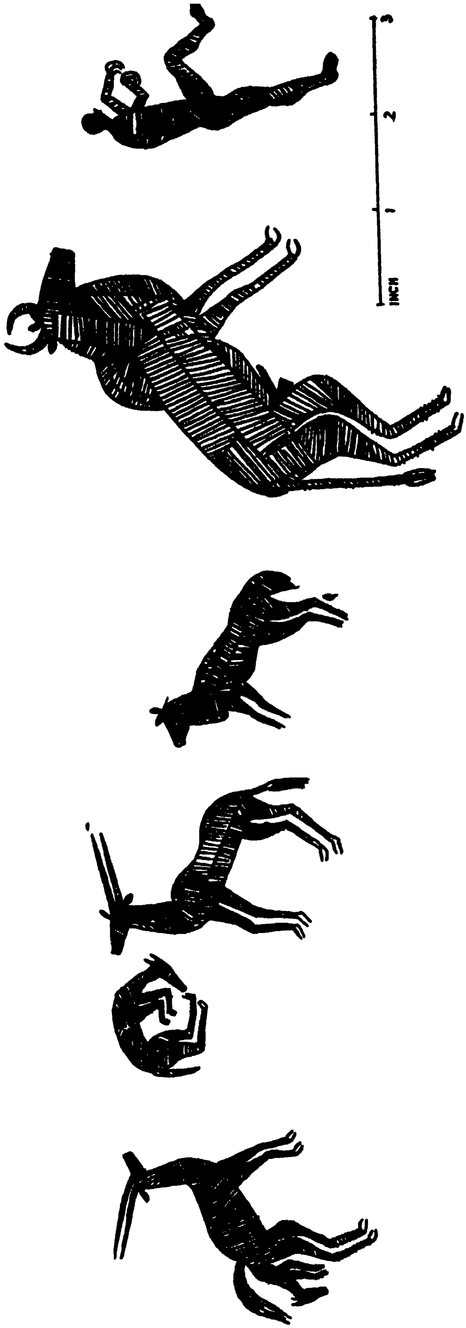
*With Illustrations.*

*Read 29th June, 1943.*

The tracings are from an ostrich egg-shell collected by Mr. G. I. M. Mzamane. The only information he received was that it was of MaSarwa origin, made by these Bushmen herders who herd cattle in the Game Reserve, and was used for storing water. It was presented by Chief Tshekedi, at Serowe. The black material filling the incised lines was simply referred to as "paint."

The incisions have been cleanly cut and very few wrong cuts were made. All the engravings except the flexed central young gemsbok, have been built up by a series of parallel strokes with the curves apparently added afterwards, the result being extremely graceful and naturalistic figures easily indentifiable, except the one animal between the gemsbok and blue wildebeest, which seems to be a zebra or a horse as a mane is apparently indicated.

It is hoped that there will be another opportunity for collecting some more of these interesting engraved egg-shells for comparison and study


INCH
1
2
3

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 330-331, November, 1943.*

# MIDDLE STONE AGE TYPES FROM BEDFORDVIEW.

BY

JOHN HARCUS.

*With Text-figure.*

*Read 28th June, 1943.*

## ABSTRACT.

The artifacts found in the flat plain north of and below Primrose Ridge—east of Johannesburg—are of yellowish brown quartzite and nearly all (99 per cent.) large. The following are shown below:—

No. (Fig.) 4. Large cleaver, glossy, no colour patina, guillotine diagonal cutting edge, 6¾in. x 4in. x 2in. (from clay-pit at brickfields).

No. (Fig.) 5. Pointed biface, fine working, 6in. x 3¾in. x 1½in. last inch of point only ½in. thick.

No. (Fig.) 6. Elliptical *coup de poing* or biface type, three well-shaped ovals, about 6in. x 3in. x 1½in., one heavily weathered.

No. (Fig.) 9. Fine core, 4in. x 3in. x 1½in., finely flaked, perfect patina.

No. 13 (Fig. ?) Unique cylindrical fabricator, beater or mallet.

No. (Fig.) 16. Biface type (2), 3in. x 2½in. x ¾in., wavy edges, completely worked.

No. (Fig.) 18. Massive side scraper or point, 3½in. x 1½in., high keeled.

Other Artifacts are as follows:—No. 1, massive boat-shaped quartzite core, 9in. x 3in. x 2½in.; No. 2, heavy and rugged oval quartz core, 6½in. x 5in. x 2½in.; No. 3, large spheroidal hammer-stone, 3½in. diameter; No. 7, crude biface type—two coarsely flaked, one with rounded point, the other with sharp point, 5in. x 5½in.; No. 8, crude biface, two, with matrix on one side, 5in. and 4½in. respectively; No. 11, cleaver, coarse material and workmanship, 4in. x 3in. x 1½in.; No. 12, crude point or pike-head on flake, butt and point damaged and restored, 4in. x 1½in. x 1¼in.; No. 14, duckbill end-scrapers, rounded one end, 2in. x 1½in. x ¾in.; No. 15, two scrapers, tomahawk shape, 2½in. x 2in. x ½in. (Kombewa type?); No. 17, coup de poing, 3½in., matrix both sides, two wavy edges, bold workmanship; No. 19, four borer points, varied material, diameters from 2½in. to 1in.; No. 20, spoon-like flakes, one unpatinated, one weathered, with glossy sunbaking on side, 3½in. x 1in. x ½in.

The remaining small fragments show work on fine blades in chert, quartz, etc., of Middle Stone Age with one or two small cores and two fragmentary n'Kewe in soft shale, 3in. diameter.

NOTE.—Owing to further excavation on the Primrose Ridge itself and large recent disclosures of artifacts, my preliminary notice of the work done there has become inadequate and is withdrawn from publication. A full account of the results will shortly appear.


Plate B.

South African Journal of Science, *Vol. XL, pp. 332-333, November, 1943.*

# UNIQUE LARGE BLADES IN PIETERSBURG CULTURE

BY

John Harcus.

*With Text-figure.*

*Read 29th June, 1943.*

The following large blades from the Northern Transvaal display novel features.

Group No. 1 appear to be a type of saw. Four specimens average 6ins. long, 2¼ins. wide at the butt, ¾ins. thick at the bulb of percussion, but reduced to an average of ¼in. on the actual blade. They are boldly serrated along both edges, and all are slightly strangulate. (Two others from the same area are in the Bureau of Archaeology.) Their rectangular shape and square cut ends (with no point) and bold serrations, suggest that their probable function was to saw, to cut through bone or branch. Plate C No. c illustrates this set of four specimens.

The second group of saws are of a smaller type and consists of two irregular flakes, alike only in each having two boldly serrated cutting edges. All six saws are in felsite, the first group heavily patinated to a rich pink, the two smaller in the natural liver-coloured felsite (Nos. D and E in Plate C illustrate this pair). In all cases, a thumb-rest flake has been taken off the top face at the butt or holding end. Recently a mass of material brought in by the Abbé Breuil and Professor van Riet Lowe from the same area contained similar specimens.

In July, 1942, in the Reed Donga, near Naboom, I dug out a long thin curved blade in felsite. The shape, the butt-end reduced by flaking to give a thumb-hold, and the sweeping curved inside edge nicely step-dressed, seems to justify the name of sickle. This specimen lacked ½in. of its point which is restored in Plate C Item A. Item B shows another less entire specimen recovered from the same area some years ago. I found another in the Salusbury Donga in September, 1942. Of the three, the first one mentioned, 7ins. long, and perfect except for the missing ½in., confirmed my previous suspicion as to their use. The sickle suggestion does not postulate cultivation: anyone who has tried to pull grass for bedding on trek, will appreciate the value of such a tool.

Plate C item F shows the shape only of a flat-bottomed high-butted tool with a flat-sloped face on the lower left hand

side. Where the flat-bottomed and the flat-sloped faces meet, chipping damage has taken place, similar to that suffered by a steel plane when misused by the inexperienced. There are two of these, both with glossy under-sides as if in their use as scrapers but in a kind of planing motion they had been worn smooth on the surfaces and suffered chipping on the fore-edge.

A further unique find is the squat cylinder 2$\frac{3}{4}$ins. diameter and 1$\frac{3}{8}$ins. high found at Bedfordview three years ago. (Plate B item ?). The periphery is strangulate as if a thong had been twisted around it, and the pecked and slightly hollowed top and undersides suggest that it may have been a kind of beater or crusher for herbs or grain. A smaller specimen of this model 2ins. × $\frac{3}{8}$in. in a granular volcanic material, was left in my care by a friend who found it in Uganda.

This is also strangulate, pecked and slightly hollowed on top and bottom. These three peculiar shapes, saws, sickles and beaters, are described in the hope of arousing discussion if similar specimens have been found by other collectors

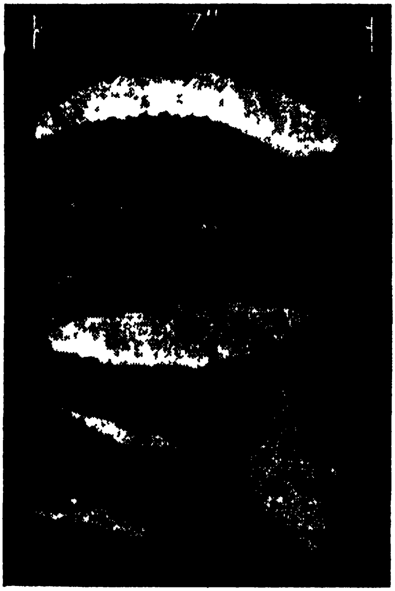


Plate C.

South African Journal of Science, *Vol. XL, pp. 334-336, November, 1943.*

# A FURTHER NOTE ON THE HEERENLOGEMENT AND ITS VISITORS

BY

Percival R. Kirby.

*With 2 Text-figures.*

*Read 29th June, 1943.*

In my paper on "The Heerenlogement and its Visitors," which I read before Section E of this Association on 30th June, 1941, I emphasised the fact that I visited the cave in order to determine whether Dr. Andrew Smith, the famous surgeon-naturalist, who visited the spot in 1828, had engraved or painted his name upon the rock after the manner of previous visitors.

But although I returned from my expedition with a list of over 170 names, I was unable, in spite of the most diligent search, to discover that of Andrew Smith.

On 2nd March of this year, however, I received a letter from Dr. Keppel H. Barnard, acting Director of the South African Museum, in which he informed me that the Mountain Club of South Africa had recently obtained from the brother of one of its former members the diary of their father, William Mann, who was under Sir Thomas Maclear at the Cape Observatory, and also the manuscript of a letter to his mother.

Mann left the Observatory on 2nd January, 1843, to help Maclear to verify and extend La Caille's arc of meridian. He had with him Dr. Wallich, the celebrated botanist ("who is on a visit to the Cape from India . . .").

He arrived at the Heerenlogementberg on 20th January. In the letter to his mother he wrote: "Visited a kind of cave at the foot of the mountain, upon the sides of which were inscribed numerous names and devices, the handiwork of the scores of travellers who have passed this spot; why such great affection should be shown for this particular place I am at a loss to conceive, but, however, since what everybody does must be right and proper, I followed the good example and left my mark there also. Amongst the names, some of which are dated as far back as 1712, I observed those of old Le Vaillant, the French traveller and naturalist; of Sir J. Alexander, Dr. Smith, etc., etc."

And in the diary we read: "The rock is covered with names, Dutch and English. I copied some of them with the earliest dates, and was much pleased at seeing the name of Le Vailant, the traveller—Sir J. Alexander also figures away—Dr. Smith's name is inscribed close under Le Vailant's—but chisel'd in probably by some other hand than the Dr.'s"

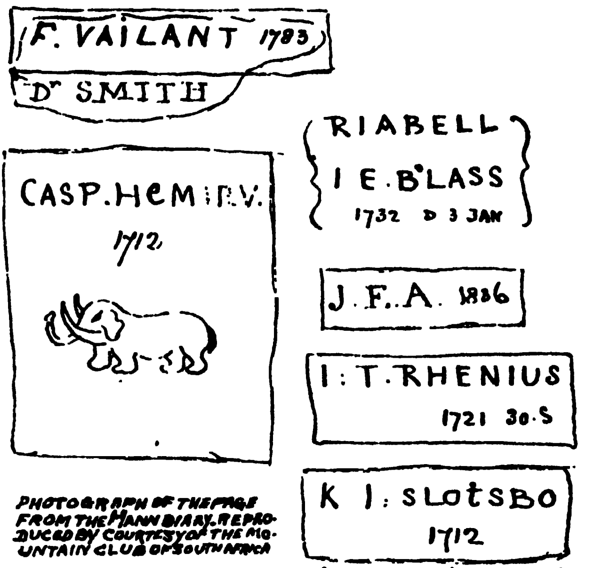
And at this point in the diary there is a page of the names copied by Mann, of which Dr. Barnard sent me a rough tracing. This tracing shows clearly the position of Smith's name under Le Vaillant's, but without a date, as well as the drawing of the elephant under the name of Caspar Hemery, 1712; but Mann does not indicate where he inscribed his own, and I did not see it when I examined the cave.

Dr. Barnard, however, thought that he could trace the T of Smith's name on the photograph reproduced as Plate 5B of my 1941 paper, and suggested that the preceding letters had been obliterated and the H written over by one of the Nieuwoudts.

I have examined a photographic print of the portion of the rock, on which the names are engraved, with great care, and sometimes I feel convinced that the lens reveals the name of Smith, and at others I am not so sure.

But in any case the new facts have compelled me to correct the entry concerning I. H. Nieuwoudt, which I placed under the date 1800. The name Nieuwoudt, which is common in the neighbourhood of Klaver, was certainly added subsequent to the visit of Andrew Smith in 1828. The date 1800 must therefore be wrong.

One more point remains. The fact that we now have definite evidence that at least four visitors to the cave engraved or painted their names on the rock face, which names are not recognisable to-day, adds weight to the suggestion which I made in 1941 that more than one inscription had been erased, and had here and there been replaced by new ones.




PHOTOGRAPH OF THE PAGE FROM THE MANN DIARY. REPRODUCED BY COURTESY OF THE MOUNTAIN CLUB OF SOUTH AFRICA

Got down to the Farm about noon with the intention of proceeding immediately to Elands R— but to my disgust I found that my cattle had bolted! — they were kneehaltered the even^g before & had absconded unseen — so here was a pretty fix — a Hot^t was mounted & sent to trace the spoor & bring them back — since 8 ok no signs of horses — this afternoon visited a spot a few hundred yards from the house where a ledge of quartz rock projects from the side of the hill — the rock is covered with names, Dutch & English — I copied some of those with the earliest dates — & was much pleased at seeing the name of Le Vaillant the traveller — Sir J Alexander also figures away — Dr Smith's name is inscribed close under Le Vaillant's — but chisell'd in probably by some other hand than the Dr

South African Journal of Science, *Vol. XL, pp. 337-341, November, 1943.*

# HEALTH SERVICES AS PART OF A SOCIAL SECURITY PLAN

BY

Dr. J. H. Harvey Pirie.

*Read 29th June, 1943.*

My task in presenting this contribution is comparatively easy. Although it is presented purely in a personal capacity, I have been so closely associated with the Planning Committee of the Medical Association of South Africa (B.M.A.) during the past two years that my views may be taken as representing the opinion of a very considerable number of the medical practitioners of South Africa.

Where I write " we " I am expressing opinions already agreed upon by the Association either in the form of evidence which has been presented to the National Health Services Commission and is public property, or will be presented as further evidence. When dealing with aspects upon which the Association has not yet finally made up its mind, or which it may not have considered, I write in the first person singular.

In opening our preliminary evidence we began with a statement to this effect:—The mere provision of more " doctoring " is no solution of the health problem of the country. Important and necessary as that may be, particularly for certain sections of the community, to begin with that alone, is tackling the problem from the wrong end. There must at the same time be a fundamental cutting at the roots of ill health—prevention must be the basic principle of a health service. Freedom from want and poverty will do more to build up a healthy community than any amount of curative medical services.

We realise that the provision of even adequate curative services is to-day a difficult economic problem. Owing to technical advances in medical services (complex laboratory diagnostic and therapeutic procedures, surgical operative technique, hospitalisation, etc.) such services have frankly become too expensive a commodity for about 80 per cent. of the population to buy, and there is no going back on this.

To meet this position, there is a demand from the public, becoming more and more clamant, for a " State Medical Service." We fear that the Government may offer them a sop by

setting up such a curative service only, putting aside the admittedly more difficult task of dealing with social security as a whole—an entity of which a Health Service should be a part.

Such action would not have our willing co-operation.

In the past the medical profession has sometimes (and, I fear I must admit, with some justification) been accused of being reactionary and obstructive when legislative proposals for improvement of medical services to the community have been on the tapis. Here, in South Africa to-day, I think I can claim that we are taking up a more progressive attitude than are the organised bodies representative of the profession in any country.

We are offering, on our own initiative, to become to a considerable degree a "socialised" body without demanding that other professions and trade should simultaneously be "socialised." We are doing so because we feel that the socialisation of health services is urgently needed, as the only practical solution of the health problem, but that to couple this with a demand for complete socialisation would get us nowhere.

We are not prepared, however, willingly to surrender our individuality unless we are satisfied that the State, as representing the people, will carry out its part of the scheme, by dealing with the basic requirements for health—freedom from poverty, nutrition, housing, etc.

We also insist that, no matter how much alteration of existing legislation it may involve, there is no hope of evolving a satisfactory health plan for the country unless it is put under a unified central direction. The present state of affairs is utterly chaotic. Health and medical services to-day are everybody's business, with the inevitable result, of course, that very often they are nobody's business. Health matters are dealt with by practically every department of State, by provincial, municipal, divisional and voluntary authorities. Many *ad hoc* organisations, good in themselves, have been set up to deal with different needs, but they have not been duly considered as parts of one general plan, and each flounders along as best it can. There may be some attempt at general direction, mainly through purse-string control, but this is unsatisfactory and the difficulties of getting things done, with the multiplicity of authorities concerned, must be experienced to be properly realised. I can only give you our view that we consider the present system—if system it can be called—quite hopeless.

We believe that a health service such as we envisage can only be carried out by State finance and by close co-operation between, on the one hand, the Health Ministry, and other Ministries affected, such as Social Welfare, Labour, Agriculture, Native Affairs, Education, etc., and, on the other, the Medical and Allied professions.

Finally, we hold that the medical and allied professions involved in health work must have a direct say, and the major say, in the organisation and control of the health service. It is on technical skill, not on administrative ability, that health depends.

You will gather, I think, from what I have said so far, that we definitely favour a health scheme which is to be only a part of a general social security scheme.

I now propose to deal briefly with the internal structure of the health service I envisage.

In the first place, I fear that some of you may say, or think, "Oh, don't bother us with this—that is purely a matter for you doctors, yourselves." If any of you feel that way, I think you are wrong. Most of you are going to be affected by the scheme, as potential patients. We feel, moreover, that no scheme will be a success which is merely imposed by authority from above; it must have the confidence and the co-operation of the people if it is to work smoothly. In other words, it has got to be—not the Government's scheme, not the doctors' scheme, but the people's scheme.

We are dead against an organised health service which would be part of the Civil Service. However suitable the Civil Service may be for some aspects of the government of the country, we do not think it would be suitable for a Health Service. A health plan, we think, must be on a long-term basis, and not be subject to the day-to-day, or even year-to-year inquisition of Parliament. In a Civil Service we would dread its being made the catspaw of party politics and we can imagine nothing worse for the health of the country than promotion in the Service becoming dependent on mere seniority or political views, instead of on professional ability. In a Civil Service, we also fear we would lose our right of legitimate criticism and advice.

The alternative which I favour is something of the nature of a Public Utility Corporation. To give the Government and the people the say which they must have as the financers, I think there should be a National Health Council composed of (1) Government nominees representing Departments, such as Health, Social Welfare, Native Affairs, Agriculture, Education, Finance, etc.; (2) direct representatives of the people; (3) technical representatives—medical, dental, nursing, etc., elected by the professional associations of these workers. This Council should be essentially a Planning Committee which would decide the broad lines of policy the health plan for the country should take, and would decide the amount of money available for it on a long term basis, say three to five years.

The personnel of the scheme (doctors, dentists, nurses, pharmacists and auxiliary technicians) should be incorporated

in a National Health Corporation, with its powers vested in a Board of Governors, with the Minister of Health as the Chairman, the members being a selection, say half, of the elected technical representatives on the National Health Council.

The Board should be charged with the duty of putting into effect the scheme agreed upon in broad outline by the Council. The money made available to it for this purpose should take the form of a block grant. It should be empowered to own, acquire or build hospitals, health centres or other things needed for the furtherance of the health plan, and, for the carrying out of environmental services, to contract with any other authority—State, provincial, municipal, etc.

This would involve, of course, a Central Medical Directorate and also, as I think excessive centralisation of control is to be avoided at all costs, centres of regional administration. These latter I think should be placed to cover areas each with a population of ± 500,000. This figure is not taken arbitrarily, but is one which experience has shown is about the right size to have a General Hospital of ± 1,000 beds. Such regions would vary enormously in size—from a single city and its environs, to huge sparsely settled districts like the N.W. Cape and thickly populated rural areas like the Transkei. The needs of the various regions would also vary largely. Around each General Hospital there might be smaller auxiliary hospitals for the less serious cases, and a number of health centres with from one to a dozen doctors attached to each. These health centres would be the foci not merely for the curative services, but also for the protective services, and for the health propaganda work which will be very necessary.

The staff at each level—hospital, health centre, etc.—should constitute itself a Technical Advisory Committee, thus providing a channel for every member to give advice or criticism. But there should be also at each level a Public Relations Committee with a senior member of the technical staff sitting as a member of it. This Committee would give the people their opportunity to have a say in the direct operations of the scheme.

All appointments in the service should be advertised, and the appointments made by Committees, not by an individual—the Board of Governors having the final approval of appointments, and being the ultimate employers. This would get over most of the difficulties attending transfers and promotions.

Such is the skeleton of my plan. It may be felt that the medical and allied professions in this are asking for too much say. I do not think so. As the experts on health matters, we have been too backward in the past. Administration as a science has lagged far behind technical achievements. Engineers have been recognised as the most suitable people to run engineering concerns, e.g., Iscor and the Electricity Supply Commission, and the Railways are run by engineers, not by the Civil Ser-

vice. Why not let doctors run health services? To put our case on the very lowest grounds—I do not think doctors could possibly land health administration in any worse state of chaos than the administrators have got it into to-day.

Such a scheme will obviously take years to bring to completion, if for no other reason than because of the insufficiency of present technical personnel to meet wants. Where and how best to start it going are difficult problems. At a meeting of the Federal Council of the Medical Association recently, this was being discussed and almost every representative stated, in effect "Oh, my area is the one most needing help." It is to be hoped that the National Health Services Commission, in their survey of the Union, will be able to determine priority of needs.

I am not touching on the thorny problem of finance. I know it is a very important side of the affair, but if this war has taught us anything it is that finance, as such, is not a a limiting factor in national endeavour. The limiting factors are the amounts of raw material, machinery and labour we possess, and our power to co-operate in their use.

Finance cannot therefore be put forward as an excuse for not taking action. Action must be based on available real resources and priority of needs. A planned health service must surely rank as an A 1 priority, but it must not encroach on other A 1 priorities—freedom from want and fear.

# RECOMMENDATIONS FOR REINFORCED CONCRETE

BY

C. Ferguson.

*Read 28th June, 1943.*

South African Journal of Science, *Vol. XL, pp. 342-346, November, 1943.*

# THE APPLICATION OF SOCIAL SECURITY PRINCIPLES TO THE UNION OF SOUTH AFRICA

BY

J. L. Gray,

*Department of Social Studies, University of the Witwatersrand.*

*Read 29th June, 1943.*

## I.

A recent publication of the International Labour Office (1) makes a convenient distinction in the field of state social welfare policy between the methods of "social assistance," "social insurance" and "systematic social security." The first, which is also the oldest, consists of measures aimed at alleviating the condition of the indigent and dependent. Such measures are often fragmentary in scope and invariably eleemosynary in administration, being financed out of taxation, accompanied by rigorous means tests and typically unrelated to a tolerable minimum standard of living. Social insurance schemes almost always require contributions from those exposed to risks and eligible for compensation; but the cost is often shared also by employers and the State. In part, at least, they have an actuarial basis. In theory they can be administered without means tests, and they are often capable of providing adequate protection against poverty arising from the emergencies of family life and earning a livelihood. A systematic social security plan is an extension of the foregoing, consolidated and made more comprehensive, designed usually to ensure a minimum standard of living for the whole population; and is often combined with measures to *prevent* ill-health, unemployment, squalor and illiteracy.

However, it is useful to contrast compulsory collective thrift devices providing money benefits in emergencies with social services and other economic arrangements, whose effect is to raise the entire level of earned income in a population. The former alone I call "social security."

## II.

Proposals for a complete system of social security have been put forward by Sir William Beveridge for Great Britain. (2) The U.S.S.R. (3) and (4) and New Zealand (5) already have fairly comprehensive schemes, differing both from each other and from the Beveridge Plan. The U.S.A. is developing a scheme of its own, with characteristic differences in aim and administration. (5)

All, however, are systematic and comprehensive in objective. Before considering the application of the principles implicit in these schemes to the Union of South Africa, it is necessary to discuss the conditions which seem to be pre-requisite for the full development of social security protection, and ask how far these exist in our own country. Because it is probably the best known, I take the Beveridge Report as an example of a comprehensive plan, and Great Britain as a country in which such a plan can, apparently, be successfully operated.

The proposals of the Beveridge Report seem to be timely and appropriate in Great Britain for the following reasons:—

(a) Existing wage levels, in conditions of "full employment," appear to be sufficient to maintain a normal working-class family above the poverty level. The national income, when part of it is saved and redistributed through social insurance, is large enough to bear the cost of protecting the wage earner's standard of living in emergencies, at least at a minimum level of tolerable subsistence.

(b) Britain is familiar with the effects of social insurances. Employers are in most cases able and willing to contribute towards the cost, being persuaded of their efficacy in conserving health, efficiency and working morale, in reducing industrial unrest and steadying the demand for the basic products of British manufacturing industry. (However, fears are often expressed lest the employers' contribution unduly raise competitive labour costs in export industries.) It is important to add that the labour force in Britain will shortly decline in numbers, while the burden of supporting the unproductive ages will proportionately increase. The young worker and the worker in his maturity become more valuable. Family allowances are proposed in an effort to improve both the quality and the quantity of the next generation.

(c) The prevailing opinion seems to be that the British tax system is elastic enough to bear additional burdens, without undue dislocation of the financing of business and new investment. It is possible, too, that the secular tendency of the economic system is towards new methods of governing industry, restricting the scope of individual or corporate decisions likely to be influenced by the profit motive.

(d) The great majority of the occupied population are engaged on a contractual basis, as wage or salary earners in industry, commerce, mining, transport, agriculture, etc. Experience shows that this enormously facilitates the collection of contributions and the assessment of eligibility for benefits under social insurance schemes. Access to the land provides little alternative security in a country lacking a peasantry. Moreover, there are no racial and few regional differences in standards of living, which assists the smooth and equitable working of social insurance.

(e) The machinery for administering a national all-in insurance system already exists, and its problems are known. The fact that the United Kingdom is a unitary state also eases the administrative problem.

(f) The basic social services are already well-developed. These help to render large-scale State assistance less necessary, by raising the efficiency of the population as creators of income. At the same time they furnish the conditions in which social insurance protection can function more adequately. While enlightened people demand that they should be continuously improved, their *tactical* importance in the war against poverty appears to have declined relatively to that of social insurance.

(g) There is reason to believe that social insurance benefits will not pauperise the worker nor significantly damage his incentive to work. The population is habituated to industrial work and to high and competitive standards of living. There is even some ground for holding that family security will encourage better work and more private saving.

(h) Great Britain has a popular system of government, and it is possible that the more urgent needs of the masses will be satisfied before the less urgent needs of the few. The tradition of collective bargaining should ensure the continuance of efforts to raise earned wage levels and improve working conditions. In other words, the dangers of State paternalism and industrial fascism, inherent in social security systems, are not so serious as in certain other countries.

None of these eight conditions hold in the Union of South Africa, ([6]) although they are realised to a considerable extent in New Zealand and Australia, with the possible exception of (c). (I omit the U.S.S.R. in these comparisons because of its wholly different social structure.) Many of them are absent in the U.S.A. Indeed, the resemblance of the U.S.A. to the Union of South Africa in many vital respects suggests that we can learn more in this country from a study of American efforts to establish social security than from a reverential perusal of the Beveridge Report.

III.

In the Union of South Africa, as elsewhere, the goal of social security must be approached in stages. Our national income per head is still extremely low. In our population of many races and standards of living we cannot achieve through any method of insurance or income—redistribution the abolition of poverty, but only its mitigation. We cannot yet abandon the non-contributory method, i.e., social assistance. A large and increasing part of State expenditure ought to go to the extension and improvement of the basic social services, like health, education, nutrition, housing and child and maternal welfare. With these limitations in mind, however, we can still do much to alleviate injurious and unmerited poverty and raise the standard

of well-being for all. We can protect all sections of the population in their most defenceless emergencies, and introduce a model scheme of social insurance, to cover a considerable number of those most exposed to the risks it is designed to compensate. We can have better old-age pensions, available to all; widows' pensions and more assistance to dependent and orphan children; a system of invalidity or disability pensions; sickness and unemployment insurance and perhaps old-age insurance. These would provide a foundation on which to build—a foundation big in relation to our existing resources, although modest compared with what is attainable in richer and more advanced countries with a different social structure.

### A—Non-Contributory Pensions.

#### (1) *Old Age.*

The extension of old-age pensions to all sections of the population presents no difficulties. Objectionable in principle, racial differentiation in rates of pension is in practice easy to administer. It is also possible to reduce the discrepancy between different racial pension-rates to a proportion lower than that which holds between average earned standards of living, thus serving the cause of distributive justice. No rate at present can be adequate wholly to remove want and anxiety from the lives of any section of the aged population. The cost of attempting it would be colossal and the effort misdirected. In a poor country the claims of the productive and potentially productive age-groups must come first. Moreover, we must be careful not to start with too high a rate, since the cost will steadily rise, owing both to the increasing age-composition of the population and to later claims for higher benefits.

#### (2) *Widows' Pensions.*

The Union lacks a scheme of widows' pensions. Their introduction involves some problems, none of them formidable. Where there are no dependent children a distinction must be made between older widows and those still capable of earning a living, or of being trained to earn a living. In the case of widows left in charge of dependent children there is a strong case for assessing the amount of assistance at a level high enough to put the family beyond the fear of want.

#### (3) *Invalidity or Disability Pensions.*

These are in general useless without proper provision for medical rehabilitation and employment training for the partially disabled and the handicapped. Such provision should be made and pensions granted to mitigate poverty in this section of the population.

### B—Sickness and Unemployment Insurance.

A contributory scheme should be instituted, with contributions from the insured person, his employer and the State,

applicable to as many employees as possible in industry, commerce, mining, transport and public administration. It would be impracticable at the beginning to include the rural population, white or black, while special arrangements would be required in the case of migratory and indentured labour. Contributions and benefits should be assessed in (say) three income categories. Benefits cannot be more than one-half of normal earnings, to discourage malingering and encourage the growth of regular working habits among our non-European population; they may have to be even less for the more prosperous workers. Unemployment benefit requires a work test, and a work test is impossible without an adequate system of employment exchanges and an economic policy aimed at providing fuller employment. Similarly sickness pay achieves its fullest justification only in the framework of a genuinely national health service.

### C—Old Age Insurance.

If it should be decided to institute a scheme of old-age insurance to supplement, and ultimately to replace non-contributory old-age assistance, it would be desirable to include as many contributors as possible. Even so, consideration of the incomes and economic status of the bulk of the rural population and of migratory labour makes their inclusion in the beginning highly doubtful. The problems of financing such a scheme are extremely complex. Probably the best model to follow would be that of the U.S.A. Federal Old-Age Insurance plan.

## IV.

Social security in the sense employed in this discussion is not an exclusive, nor the paramount aim of a sound State social welfare policy in South Africa. To promote maximum social welfare our primary needs are (1) greater economic productivity involving, *inter alia*, the better use of our labour resources; (2) better social services; and (3) more democracy and improved economic opportunities.

### References.


(1) International Labour Office, Montreal: "Approaches to Social Security." No. 18, Series M. (1942).

(2) Beveridge, Sir W.: "Social Insurance and Allied Services, Report." *Cmd. 6406.* H.M. Stationery Office, London (1942).

(3) Webb, S. & B.: "Soviet Communism." pp. 826-7. London (1935).

(4) Dobb, M.: "Social Insurance in the Soviet Union." Nat. Council for British-Soviet Unity, London.

(5) Batson, E.: "Towards Social Security." Cape Town (1943). Contains a summary of the provisions of the N.Z. Social Security Act of 1938, pp. 79-83.

(6) Idem. Idem. pp. 89-91.

(7) Carter, I. G. (Ed.): "Appraising the Social Security Program." *Ann.Amer.Acad.Pol.Soc.Sci.*, Vol. 202 (1939).

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XL, pp. 347-349, November, 1943.*

# SCIENCE AND THEOLOGY: 1860-1940

BY

THE ABBÉ H. BREUIL,

*Abstract of an Address delivered on the 28th June, 1943, in offering the thanks of the Association to Dr. R. Broom for his Presidential Address on the "Origin of Man."*

When we call to mind the memorable exchange of compliments between Bishop Wilberforce and Thomas Henry Huxley at the historic meeting of the British Association for the Advancement of Science on the 30th of June, 1860, the honour conferred to-day upon a Churchman by an invitation to express the thanks of the South African Association for an address by an eminent evolutionist on the "Origin of Man," indicates the enormous distance traversed in the last 83 years by the votaries of both Science and Faith, and their present spirit of loyal and cordial sympathy in the realm of practical discovery and mutual comprehension.

With a competence no one can question, and with incredibly disinterested toil, Dr. Broom has drawn for us the outline of an evolution to which he has himself contributed so much, first by his work on the strange reptiles of the Karoo formations and then on the proto-men frequenting South African caves some hundreds of thousands of years ago, an evolution the influence of which on the attitude of the human spirit of religious man I wish to illustrate with some recollections showing how this spirit has moved and adapted itself to questions arising from the facts discovered.

Firstly, in 1893, fifty years ago, our great Pope Leo XIII, with remarkable wisdom, warned the theologians that to claim to seek scientific teaching in the Bible, was running the risk of turning all into ridicule. "In considering the truths which a Christian can draw from Holy Writ," said he, "one must use common sense, and the literary type of each of the books composing the Bible must be studied, whether they are history, tradition, legend or philosophy."

A truer conception is thus gained of the reciprocal limits of experimental Science, Metaphysics and Theology. In former days their frontiers were frequently invaded by the representatives of one or another of these subjects, who claimed to teach, without sufficient preparation, what they did not understand because of lack of preliminary study, but, like Wilberforce,

plunged into scientific questions with which they had no real acquaintance, only to obscure them by an aimless rhetoric, and to distract the attention of their hearers from the real point at issue, by eloquent digressions and skilled appeals to religious prejudice.

We now know that the worst spiritual pride is to claim to speak about that of which one knows nothing, above all to hold forth about abstract principles, which have nothing to do with objective science, or vice versa. That is what Cardinal Mercier freely acknowledged, in the last springtime of his life, when, during a long audience I had with him, I told him that Evolution was not what most people thought, but a method—a moving panorama, and not a hypothesis. The Cardinal commented on this definition, saying: "Evolution is a scientific method applied to things happening in time; everything derives in part from its antecedents, and also in part gives birth to what follows. All study of historic problems about the Cosmos, the World, Life, or Humanity must therefore be defined as evolutionary, both the method, the working hypothesis suggested and used provisionally, and the increasingly enlightened point of view to which this study leads by the grouping and interpretation of declared facts."

A system of investigation, a way of development, such is the method, the object and the limit of all objective scientific research. But the intimate nature of the thing developed, the hidden reasons controlling this development to a predetermined end, not ruled by chance—that lies outside the domain of scientific study. Not that I am against a scientist studying that as well, but not as a man of science; he must then be a philosopher, a metaphysician, and must use the "introspective" methods of such thinkers.

It is one of the curious reversions of things on this globe to see palaeontologists to-day, and Dr. Broom amongst them, following the same trend of thought which leads to an affirmation of the existence of the spirit modelling living matter by the personification of "natural forces." And if, in the course of ages, living matter displays progressive faculties of perception and action, inexistent in earliest times, these must certainly spring from an underlying spiritual principle, which outside stimulation brings to the surface bit by bit, when the environment is favourable, in the same way as was held by St. Augustine, following Platonic philosophy.

Thus, the problems which, a few generations ago, troubled the minds of the public, have cleared up and the whole outlook has been widened. As Pope Pius XI said to me in July, 1935, when I presented to him the first photograph of a Neanderthalian skull found in Rome a few days previously, "Facts are not hypotheses; they are realities which we must link to what we know already and must then discover more; when there are enough, a teachable theory will arise which must be reckoned

with." Wise and prudent words of a scientist, more familiar no doubt with other aspects of Science, but words which apply to all types of research.

And if I am a practical man of science and yet a Churchman, may I remind you that amongst the great discoverers of various fossils and those who have built theories on these discoveries, I am not the only one of my type. The Jesuit Father Teilhard de Chardin made a great contribution to the advancement of our science at Piltdown, as well as in China. The celebrated Neanderthalian skeleton of Chapelle-aux-Saints was discovered by my friends the two Abbés Bouyssonnie; and the great prehistorian Hugo Obermaier is also a Churchman. The science of fossil Man apparently does not get on so badly with the Christian Church and its representatives; and the "Ascent to Parnassus," as H. Fairfield Osborn called it, goes on with twofold glance, towards the Earth, holding the remains of the first essays of our type, and towards Heaven, to which our spirits bear us up and to which, as God's children, we are drawn.

## SCIENCE AND THE NEW FIVE-DIMENSIONAL ASPECT

BY

DR. R. J. JORDAN.

*Read 29th June, 1943.*

South African Journal of Science, *Vol. XL, pp. 350-358, November, 1943.*

# A MAJOR PROBLEM IN EDUCATIONAL POLICY: THE NATURE AND THE EXTENT OF THE UNITY OF AGRICULTURAL EDUCATION

BY

Professor A. J. Boyazoglu,
*Universities of Thessaloniki (Greece) and Witwatersrand. Johannesburg.*
*Counsellor to the Royal Government of Greece.*
*Director of Rural Economics Survey of the University of the Witwatersrand.*

*Read 29th June, 1943.*

## I—The Problem.

Is there a unity in agricultural education? If so, what is the nature and extent of the interdependency of its main branches?

This problem may be divided into two sub-problems:

1. Are the various branches of agricultural education independent of each other and of different absolute and relative values; their difference being of such a nature as to justify, under given conditions, preference being given to any of them in accordance with existing conditions?

2. Is specialisation in agricultural education in the various branches of production (i.e., plant husbandry, animal husbandry, rural technology) and further specialisation in sub-branches (such as field husbandry, horticulture, forestry, etc., or horse breeding, cattle farming, sheep farming, etc., or dairying, wine manufacturing, etc.,) desirable; and how does such specialisation affect the unity of agricultural education? Further, what is the value of general agricultural education for the " specialist " and what has agricultural education to gain from " general education "?

What general conclusions can be drawn from the answers to these two sub-problems for the solution of our problem; and what will be the consequences with regard to the educational policy?

## II—Fields Covered and Importance of Agricultural Education.

### 1.—*The Contribution of Agricultural Education to the Work of Rural Policy.*

(a) The Absolute Value of Agricultural Education.

In order that a scheme or even a simple measure of rural policy be put into practice, it is evidently necessary: (1) that

there should exist a research, educational, field and administrative staff, adequate in numbers and ability; (2) that those who are mainly concerned with the agricultural policy—i.e., the farmers—and who apply and actually carry out the major part of the measures or the entire scheme should also have the minimum appropriate technical and other knowledge; (3) that those in control of the economic policy should possess at least the knowledge required to enable them to separate and appreciate the agricultural factor from the economic, financial, social and national viewpoints, and thus be in position at all times to take the appropriate steps or impose the necessary sacrifices; (4) that society at large, and especially the leaders of every country should have understanding of and sympathy for agriculture.

(b) The Relative Importance of Agricultural Education.

Knowledge may be transmitted by tradition or by education. Tradition, however, is a very slow means of spreading knowledge and is practically limited within the narrow bounds of routine adapted to distinct conditions. Its achievements cannot be compared with those of science. Education is, therefore, of extreme importance, particularly in filling the gap between traditional routine and the progress of science and technique. Thus agricultural development is largely dependent on the successful teaching of agricultural science.

In a "paper" read to the South African Association [1], stress was laid, in accordance with their respective merit, on the importance of: (a) the achievements of agricultural and related sciences, (b) the progress that agriculture has made, thanks to these, and (c) the advantages drawn by social economy and civilisation therefrom. Yet it is evident that the most wonderful achievements in the field of scientific research would have been of little use or practical importance, if they were "kept hidden under a bushel." That would certainly be the case, if agricultural education did not provide the means for the dissemination of the results of scientific efforts.

The number and ability of a properly educated staff is hardly less important than the sufficiency in material and economic means. A correct estimate in time and space of a given situation, the right use of the means available and the application of the most commendable methods and combinations will in themselves effect considerable progress without any additional expenditure; whereas an incorrect approach to the problems of rural economy may often result in incalculable losses. In cases where the producers, their guides and their administrators lack sufficient education, there is a surprisingly great decrease in the efficacy of most measures of rural economy. Quite often, measures and material sacrifices turn out to be valueless, or even have a detrimental instead of a beneficial effect.

(c) Conditions Under which Education Becomes Increasingly Important.

The value of agricultural education becomes greater as the need for intensification in rural economy becomes more pressing and as the different factors of production and their combined working become more complicated.

Agriculture is becoming more and more intensified and complicated; hence the constantly increasing need for an enlightened farming community and a highly trained staff to direct its activities.

### 2.—*Aims of Agricultural Education.*

Now, the securing of the above-mentioned efficient staff of scientists and community leaders, the preparation of the agricultural population for the application of advanced scientific methods and technique, and the creation of a favourable social atmosphere, all constitute the functions af agricultural education. This fully explains the paramount absolute, as well as relative importance of agricultural education, within the frame of rural policy. Consequently, among the primary measures in any good and approved scheme of rural policy there should, obviously, be arrangements for the appropriate organisation of agricultural education, thoroughly equipped with suitable teaching staff and material.

## III—The Main Branches of Agricultural Education.

From the objects of agricultural education mentioned and the vastness of the field covered by agriculture, the need for agricultural education to adapt itself to a series of conditions and requirements is obvious. On the other hand, the previously mentioned paper ([1]) made quite clear the great variety and the breadth and depth of the branches of science—agricultural sciences proper and auxiliary sciences (applied to agriculture and pure)—to which agriculture must have recourse for the accomplishment of its social mission.

Hence the great number and variety of branches and forms of agricultural education ([2]) and ([3]).

These branches if grouped in a rational manner, i.e., taking as criteria the main objects aimed at by the various branches and forms, and the methods and means utilised in each branch or form—instead of the traditional way, consisting of following the educational levels or school standards (Elementary, Secondary or Higher)—would present exceptionally interesting signs and indications for the study of things pertaining to agricultural education, from both the static and the dynamic points of view.

Agricultural education comprises two basic branches: (1) The School Agricultural Education (or agricultural education proper) and (2) the Extension Services.

### 1.—*School Agricultural Education.*

This can be sub-divided into four main branches: (a) the teaching of agriculture—as one of the subjects—in ordinary

schools, (b) agriculturally-biased education, (c) vocational agricultural education and (d) scientific agricultural education.

(a) Agriculture as a School Subject in General Education Institutions (Ordinary Schools).

This type of agricultural education just gives the student an idea of agriculture, its objects, its importance, its methods, its means, its achievements and its possibilities. It is provided in ordinary primary, secondary and even higher education institutions (such as teachers' training colleges, etc.) as one subject of the syllabus.

(b) Agriculturally-Biased Education.

Agriculturally-biased education is given at a special type of institutions (such as the "Becker School-Farms" of South Africa), providing the ordinary primary or secondary education in an agricultural environment. Such educational institutions have the advantage that pupils do not lose contact with the conditions of agriculture during their general primary or secondary education.

But what is more important is the "test" to which the student is submitted during his stay in the institution. If a student does not like agriculture, and is more interested in other vocational branches, such as carpentry, mechanics, accounting, etc. (for which there are also facilities in the school), this vocationally-biased school will reveal his natural bent to his teachers, and he will be selected for the work he is best suited for. Such schools, therefore, aim more at vocational guidance than at vocational training.

(c) Vocational Agricultural Education.

Vocational agricultural education aims at teaching agricultural vocations, i.e., at training farmers, farm managers, farm foremen, peasants and labourers. It may be of three types: (a) Elementary, concerned with the enlightenment of peasants, small settlers and farm workers; (b) secondary, having as object the education of farmers intending to farm on medium-sized farms, also farm foremen; (c) higher or technical (colleges of agriculture of a sub-university standard) for preparing farmers intending to farm on a large scale or going in for intensive farming and also farm managers.

These are the main branches of vocational agricultural education.

(d) Scientific Agricultural Education.

Scientific agricultural education is provided in universities and aims at the preparation of agriculturists intending to work for the promotion of agricultural science, educationists, agricultural civil servants, technical advisers to farmers' organisations, farm managers of big concerns, and persons intending to go in for farming on a very large scale.

2.—*The Extension Services.*

The educational effort of the extension services aims: (a) at providing: (i) the farmer, usually on his farm, with the special information and advice which he requires concerning his enterprise and farming proposition, (ii) assistance to farm women in the management of their home economics; and (b) at promoting the rural club type of education amongst children in the country districts.

3.—*Other Aspects and Forms.*

Besides these main forms, there are a number of others, some of which may be considered as intermediate and/or introductory or complementary to those already mentioned.

This variety is easy to account for, if we take into consideration that agricultural education practically concerns people of all types, of all origins and of all ages and all kinds of farming activities.

IV—SPECIALISATION.

Agricultural education may be general or specialised. Specialisation is often desirable in vocational agricultural education; it is usually a necessity in advanced scientific agricultural education; and in many instances, it is inevitable in the agriculturally-biased education; but it is inconceivable when agriculture is taught as an ordinary school subject.

The lines in which specialisation takes place are usually those of the main branches of agricultural production (plant husbandry, animal husbandry and technology), or their sub-branches; but it may also concern rural economics, home economics, plant or animal pathology, or any sciences applied to agriculture. Anyhow, all and any specialisation has to be founded on a previous general agricultural education—varying in extent and in depth, according to the case—and the latter on an all round general education.

In fact, agriculture has a very broad field of activity, and its various branches are closely interconnected and interdependent. On the other hand, agricultural sciences mainly make use of synthetic methods (1) and have to rely upon a great number of auxiliary sciences (1).

V—THE METHODS AND MEANS.

The methods and means employed in each of these branches of agricultural education can be summarised as follows:—

1.—*School Agricultural Education.*

(a) When agriculture is taught as a school subject, students follow demonstrations in the school plot or garden, and make some agricultural excursions; but the teaching methods most in use are the same as for the other subjects of the syllabus, especially those in use in natural sciences, consisting of lectures, and laboratory and class room demonstrations.

(b) In the agriculturally-biased schools, the students, besides their general education courses, follow in practice, during some

of their spare time, the whole procedure of farm management and perform the different kinds of work that are done on the farm and/or in its workshops and/or in its office. Apart from this, boys usually take agriculture, and girls home economics—as a subject—in their general education curriculum.

(c) Vocational agricultural education.

(i) If elementary or practical, follows the principle of Aristotle: "Learning by doing." The lectures are given on the spot in an explanatory way. The students perform the task and the instructor explains to them how a thing should be done and, as far as possible, why.

(ii) In secondary vocational education, the students devote about half of the day, or three days out of the six, to practical work. They follow series of lectures and demonstrations and do some laboratory work.

(iii) In higher vocational education, the students usually devote one-third of their time to agricultural practice and/or the performance of other farm work. They receive series of lectures of a higher standard on science, economics and agriculture, follow demonstrations and do more advanced laboratory work. When graduating they should not only know how different farm activities ought to be carried out, but must further be in a position to face the various problems involved in farm management and to know the right method to obtain the best results in each case. They must be able to control their workers, and should know as far as possible the "why" of every farming practice.

(d) The teaching "in extenso" of positive and social sciences and of their applications in the field of agriculture, as well as of some applied sciences (such as engineering) constitutes the foundation of scientific agricultural education. Agricultural science must be on a proper basis; previous or subsequent agricultural practice of at least one year is absolutely necessary. The students follow lectures and demonstrations, work in the laboratories and must have at least one day per week of agricultural practice. Some training in scientific research, and in particular in the methods and means used in handling scientific problems in agriculture, is also necessary. They will not all become scientists and it is not necessary for them to go into details of scientific method, but they must all acquire and be able to maintain a scientific attitude.

### 2—*Education Through Extension Services.*

The basic methods employed by the extension services are to a large extent different from those in use in school agricultural education. They aim at educating the farmer, his wife and family by making use of every opportunity that offers itself.

The most important work in this type of agricultural education is that done by the "extension officers." These officers are often in charge of auxiliary work as well, but their main object is to educate and give advice to the public, and particularly the farming community.

The following are some of the most successful methods in use in extension education.

(a) Co-operative demonstration. This method consists in making use of the co-operation of progressive farmers to demonstrate locally the use of certain crops, propositions or systems of farming. All farmers in the district are periodically invited to inspect the result of the demonstrations.

(b) Lectures and demonstrations at "Farmers' Days" or other gatherings at a central place in the district.

These lectures and demonstrations provide the farmers with the particular information which is of special local interest; i.e. pruning of trees in a fruit area, wool classing in a sheep area, etc.

(c) Meetings for farmers' wives and daughters at which officers of the rural home economics institutions, lecture and demonstrate.

(d) Organising rural clubs for children of farmers; the main aim being the development of their interest. The "farm project" method is the one most in use here. Besides awakening his personal interest, it develops the personality of the student. The idea is not to let the student do a piece of work mechanically, but to entrust to him a full farming proposition (e.g. the fattening of a pig) at his personal financial responsibility.

## VI—The Unity of Agricultural Education.

There have been long arguments in the past about the branches and forms of agricultural education, which should be given preference in the various countries and regions, in accordance with prevailing conditions.

It is quite clear that there may be indications in favour of a bigger development of one or more branches and/or forms of agricultural education, depending on the conditions—varying from place to place. Also, it is obviously advisable that an adaptation of certain branches of agricultural education through specialisation (in agronomy, horticulture, forestry, sheep farming, beef farming, dairying etc.) should be attempted in a way to fit in with the nature of the agricultural production of each farming region.

However, notwithstanding the above, there is an indubitable unity in agricultural education; a unity not only from a philosophical and scientific point of view, but also with regard to its practical pursuance. The various branches and forms of agricultural education may be likened to a chain; the strength of which depends upon the weakest link.

We must have research scientists, field officers, educationists, farm managers, capable farmers who can manage farms of any

size, foremen and farm labourers with sufficient education, and peasants and settlers who will be able to understand the advice given to them by the extension officers. Further, it is hopeless to try and make a farmer out of a man who has no inclination for such a vocation, and no one can contest the importance of agriculturally-biased education in this respect. This type of education further enables the farmers' children to keep continual contact with agriculture; it also helps to lay the foundation of future understanding between farmer and non-farmer. Yet a more generalised sympathetic attitude towards agriculture and the rural community is of paramount importance in promoting farming interests, as well as for the general welfare. Hence, also, the advisability of including agriculture as a subject in the curriculum of schools which provide general education. On the other hand, this broadening of the outlook is of particular educational value to the city child.

## VII—Conclusions.

1 (a) *The field covered by* the objects of a system of *agricultural education* is far broader than usually considered; its utimate object—within the frame of each country—being the prosperity of the nation, and its integrated object being the welfare of the human race.

(b) *Agriculture* and *agricultural science* are of a synthetic character. On the other hand, the branches of science to which agricultural education must have recourse are numerous and of various nature.

*Therefore* (i) although agriculture is definitely realistic, the background of *agricultural education has to be humanistic.* (ii) *Specialisation* in one of the branches of agriculture or agricultural science, i.e., a knowledge of a part—however thorough it may be —is undesirable and may even be dangerous without sufficient knowledge of the whole, i.e. without a previous *general agricultural education* and without a *background* of the more general frame within which agriculture and agricultural sciences are functioning. (iii) All educational systems concerning agriculture have to be *founded*—directly or indirectly—*on as wide a basis as possible*, constituted by a very large part of the achievements of man in the various branches of science, art, technique and philosophy.

2 (a) *In classifying* and grouping the various *types of agricultural education*, it is advisable to take as *criteria:*

The *objects* pursued by each and the *methods* and *means* each makes use of, without regard to the level or standard and the degree of specialisation in each group, which are to be considered only for further sub-divisions.

The following main *branches* of agricultural education would then arise:—

(i) The school agricultural education.

(ii) The extension type education.

The first comprises four main branches:—

Agricultural education *as a school subject.*
*Agriculturally-biased* education.
*Vocational* agricultural education.
*Scientific* agricultural education.

The first three of these branches may be of elementary, secondary, or higher standard, while the fourth can, obviously, only be of a university (highest) standard.

The *extension type education*, comprising extension work proper and club work, constitutes an indispensable complement of the school type of agricultural education. Its major value lies in its filling the gap between the—constantly progressing—science and the traditional practice.

(b) With regard to school agricultural education, no real *specialisation* is conceivable within the frame of the first and partly of the second of the above branches, whilst vocational and scientific agricultural education, may either be general or concern special lines of agricultural production, pertaining to plant and animal, husbandry and rural technology. Education provided to the farming community through the extension services is of a special character and concrete.

8 (a) Although the aforementioned main branches of agricultural education, contribute to the pursuance of the same ultimate object and present many analogies, yet they constitute absolutely and distinctly different things.

(b) No preference can be given to one or more of these branches of education over the others, except with regard to sequence; by no means can one branch be substituted for another; nor can any one of them be omitted from an educational system. Otherwise, not only would the efficiency of the system as a whole be diminished, but that of the remaining branches also would decrease, in the pursuance of the objects of the educational and the rural policy aimed at. *These branches are inseparable and constitute together an indivisible whole.*

ACKNOWLEDGEMENT.

The manuscript has been read by my colleagues, Professors: E. Balogh, J. Y. T. Greig, L. F. Maingard and J. Phillips, and by Messrs. A. G. S. du Toit and I. Glyn-Thomas.

To each of these the author expresses his gratitude for their constructive criticisms.

REFERENCES.

(1) BOYAZOGLU, A. J.: "Agriculture and Science." Johannesburg, 1942; and in South African Journal of Science, Vol. XXXIX, pp. 150-151.

(2) International Institute of Agriculture: Agricultural Education in the World, Vols. I, II, III; Rome, 1935, 1936, 1938.

(3) SERBAN, M.: "L'enseignement Agronomique Superieur." Cluj, 1937.

South African Journal of Science, *Vol. XL, pp. 359-371, November, 1943.*

# MEASURING THE HOUSING PROBLEM.

## *A Critical Assessment of Methods and Techniques with Particular Reference to the Contemplated Union Housing Survey.*

BY

L. Silberman,

*University of the Witwatersrand.*

*Read 29th June, 1943.*

We find the following statement in Report No. 1 of the Social and Economic Planning Council:

> "In all respects the Union is ill-prepared to embark on housing schemes as a means of facilitating re-employment. . . . No large-scale housing schemes have been prepared. . . . The Housing Board is a part-time body with no technical staff. . . . While the Housing Board, with the co-operation of town engineers, has experimented with certain substitutes, the investigation has, in the absence of the necessary facilities, been neither systematic nor comprehensive." (1)

The need for shelter, unlike that for toothbrushes or combs, is absolute, its utility is universal. With accessories, internal furnishings and outside environment, houses are man's prime medium for the externalisation of his life values, the peace with and progress in the society, of which he is a part. Housing schemes, moreover, are fertile fields for capital investment as which they have a revivifying effect on many spheres of the economy reaching far beyond the boundaries of the building industry proper. In periods of depression housing projects become the expansionist public works programme par excellence.

Little wonder, therefore, that even a government so doggedly quotidian as that given to South Africa in the last Parliament eventually moved to plan. Silent—or negative—to all the other recommendations contained in the Report of the Planning Council, the Government accepted and even went beyond the proposal of the Planning Council.

Whereas the Council had visualised housing as one of many research subjects to be studied by the Universities all-in Regional Surveys (or by an ambitiously conceived nation-wide Town Planning Committee—it is not quite clear from the text which of these bodies should do what), the Government contemplates the appointment of a separate committee of housing experts. Not much is known of the committee's composition or terms of reference other than that it is to make

an estimate of the Union's housing needs for the coming five years.

## The Likely Position After the War.

Since its earliest days the Union of South Africa has faced a great shortage of houses. The position was very critical after the last war, when building had stopped for several years, and although public provision of houses was inaugurated in 1920, it was never on a scale sufficient to reduce the exorbitant rents customary in the country. Increasing wealth and increasing population formed a demand considerably in excess of all supplies, public and private. It was learned that private enterprise does not or cannot provide low-rental houses unless subsidised to do so because of the large initial outlay involved in even small structures and the economic insecurity of small consumers. Danger of obsolescence, changing standards, new cheap building materials. neighbourhood blight and migration, the high cost of repairs, of legal transfers, of loans, the lack of prefabrication, the fear of Government pressure on landlords, etc.—characterise an industry having to supply a very expensive and immobile commodity, but composed of producers, smaller and more unorganised than known anywhere else in our economy.

High rents—on the average 300 per cent. over the English level, are one of the causes of poverty and malnutrition.([2]) The war-time measure of pegging rent charges when prices and incomes are generally rising will only lead to a higher standard of living if it is followed by a great deal of public building as soon as the war ends. For it is evident that restrictions, if they are not to frighten the private builder out of business cannot be extended to newly erected houses, so that if their rents are to be low their supply must be ample.

Whatever we do the situation after the war will be a difficult one. Inheriting the consequences of lags and shortages of the inter-war years, deprived of all civilian building during the major part of the war, the country will have to face a continued tightness in all the factors of production, simultaneously with a tidal wave of new demand. The supply position can improve only slowly in the absence of large imports of building materials, because of the pressing needs of devastated Europe taking first place. As a going concern the industry will have to piece itself together again, and we know from the last post-war period that the efficiency of an English bricklayer declined from an average output of 1,000 bricks per day in 1914 to 300 in 1920. As wages on the other hand had risen nearly two and a half times during that war, building costs for 100 bricks in 1920 were equivalent to the cost of 700 bricks in 1914.([3])

Nor is it sufficient to have a good supply of carpenters if bricklayers are wanting in the required numbers to work with them.([4]). The building trades, already an ageing group of occupations before 1939, have since been further starved of apprentices.

On the demand side we have not only to reckon with a steady increase of the population, but with an exceptional increase in the demand of separate dwellings due to the large number of new marriages and births which regularly occur after a war. Moreover, there are many marriages contracted during the war period but not leading to an articulate demand for new dwellings because one or both of the spouses was or were on active service. Although little is said about Homes-for-Heroes this time, the returning soldiers of total war promise nevertheless, to be challenging rather than demure, tumultuous rather than docile. Even the long suffering non-European may be less prone to take without protest to the living quarters which await him on his return from the big war. What the position will be if the 10,000,000 immigrants from Europe, canvassed so assiduously in certain quarters as the solution of our economic problems, make their entry on to the scene one fails to envisage. The internal migration also may be large, but that can in time be reduced by planning.

It is, however, not inconceivable, that the degree of overcrowding may be such that the position gets out of hand and houses turn into slums faster than they can be rehabilitated or replaced. Such a calamity is not very probable, for epidemics and high mortality rates will come to our rescue and reduce the shelter problem to workable proportions by liquidating the number of those who would be in need of shelter.

### THE HOUSING SURVEY: ITS USES AND ABUSES.

Grim, anxious and foreboding as the future may appear it will be many times worse if planning is not taken in hand energetically and in time. Should the moment of reconstruction arrive and find the planner wanting, the way will be left clear to the unsettling activity of the individual speculators. It is understood that any piecemeal building must be slower and costlier than large scale planning.

How then should planning proceed? In spite of all the talk about planning these days a perusal of the literature will leave the reader with a feeling of emptiness. Little guidance on the practical steps is offered to the legislator or administrator. Only in one respect do writers on social planning agree: viz., on the need for surveys. Just as we make continuous use of geological and geographical mappings, so, it is thought, do we require detailed sociographic studies. Thus the Social and Economic Planning Council, tired of making bricks without straw, insists on the provision of systematised information on the economic and social set-up and the country's resources.([5])

To say the least such realistic monographs are educational. They enhance that spirit of impartial and painstaking enquiry which contributes so effectively to the liberal spirit.

What is not quite so readily appreciated by those who are most eloquent in their demand for surveys is that such massive accumulation of data on every conceivable subject will

not save the planner the trouble of theoretical thinking. If many American surveys make such unsatisfactory reading, the reason quite possibly can be traced to the uncertainty and confusion surrounding the objectives for the realisation of which these surveys were undertaken. Unfortunately, the realm of fact is infinite and where no determinate working principle of selection is stated explicitly the surveyor in the field is a slave of his own unguided predispositions. If the data collected are irrelevant the survey cannot be saved by splendid presentation. As Aronovici ([6]) puts it:

> "A survey is often merely evidence that under a given set of wrong assumptions or generalisations one can build up a set of facts which would justify action in harmony with these assumptions. . . . We have (especially in the housing field) accumulated a considerable number of prejudices, superstitions, and habits of thinking which befog the issue and confuse the investigators so that they accept beforehand meanings and words and correlations of facts which have no scientific value and which, in the end, are not comparable with the main objects of housing studies and the application of the findings to housing reform."

Evidence goes to prove that where an outline plan existed first, as in the case of the imposing Tennessee Valley Authority, a subsequent survey of the detailed factors was a success. Likewise a survey which sets out to measure a limited but precisely defined set of social phenomena is likely to beget useful results. Action followed the English Overcrowding Survey because its information was precise and answered an urgent question. ([7])

## National, Regional or Local Surveys.

The Government has not yet accepted the idea of financing regional surveys. Discussions are in progress, however, between the Planning Council and certain Universities. The suggestion of a regional survey is a new one to this country, and is modelled on recent English and American work. There are serious differences between the old countries and the Union, which is industrially so new, socially so fluid, and culturally so uneven. Regions are rather the end product arising at the planning stage than a point of departure.

There is a technical argument which must be considered too. National surveys might by-pass such tiresome obstacles as staffing difficulties and co-ordination of independently working centres. None of the social scientists in the Union, I think, claims for himself authority to pronounce views on the entire field covered by his subject, whereas on such matters as he has formed well-founded conclusions his knowledge and contacts are often national in scope. A limited realm of enquiry but broadly conceived geographically will also reduce that complex problem of interdepartmental collaboration of individualist

academic personalities. It may be easier for a department of one university to pool forces with a like department in another university than for that departmental head to achieve unity of outlook with another professor in the same university. Local surveys may meet similar difficulties of standardising their investigations in addition to the uncertain quality of local workers.

### Types of Survey.

If the trend of our argument seems to point to national surveys, we must still define what we mean by "survey." The term survey is misleading. Its aim is not to give a general impression but to make a minute enquiry into facts. A panoramic picture presented by a travelling commission will not suffice. Quantitative studies—of some selected areas—should be attempted if only to increase the confidence that can be placed in the qualitative conclusions. The impressionist survey will help to define a problem and it will reduce the tangled problem to a limited set of questions—yet sooner or later we must come down to measurements.

Some will argue that war time is the worst possible time for sociometric studies. They are time absorbing and costly without leading to conclusions which will be valid in the post-war world, which may see revolutionary changes. This cannot hold good for the immobile, durable, inelastic commodity of houses. In this field a precise inventory giving information about the number and size of the nation's stock will be essential in all possible worlds.(8)

The sanguine belief in short cuts presupposes surely that we know the lay of the land. Alas South Africa's social conditions still await scientific exploration. On closer examination our Government statistics are more remarkable for what is omitted than what is included in the reports. Take, for instance, the 1936 census, the last "complete census of the whole population of South Africa," that is available. Volume VIII is devoted to "Dwellings." We may quote examples of the "completeness" of its tabulations:

> "With the exception of dwellings in certain rural suburbs of large towns the tabulation has been confined to urban areas."(8)

A Union-wide census is limited to urban areas!

> "As the majority of dwellings are of from three to six rooms, most of the tables deal exclusively with dwellings of this size."

The figures for the very poorest and the most over-crowded areas are omitted.

> "Similarly, dwellings built of materials other than bricks, stone, brick and stone, and concrete form only a very small percentage of its total and are excluded from most of the rent tables."(9)

The writer must be thinking of dwellings occupied by Europeans only. When we come to native housing, notwithstanding the fact that this section of our population gives rise to our most thorny planning problem, no detailed publication of any of the ascertained housing data was undertaken at all in 1931—" on account of financial stringency of the country."(10)

If a statistical service is so starved of funds that it cannot even work up the data collected, it does not inspire much hope of having money to investigate more than the absolute minimum required for the day to day routine of government. Nor can too much reliance be placed in the material collected by the various municipalities in the absence of any sort of central supervision or agreement among local authorities upon the definition of the items mentioned. Only those who believe in an automatic and early return to *laissez faire* can defend the estimates of the Department of Census and Statistics.

### Surveys Instead of Commissions.

The Union has had good and bad commissions on a great number of controversial questions, but rarely have the Commissioners or the witnesses been statistically minded, or if so inclined, been in a position to make quantitative assessments. We should take a leaf out of the book of the Union's sister dominion, Australia, to appreciate the value and use that can be made of government statisticians—and statistics. If it is admitted that facts are superior to intuitive opinions it is held that information as supplied for Australia is out of the question here for lack of personnel. Should the position be as serious as is made out then we should train the personnel. Analysts must be highly trained, whereas enumerators can be relatively unskilled as long as the instructions given to them are precise and unambiguous and supervision is continuous. What knowledge we have of non-European enumerators has confirmed this statement, and there is reason to suppose that the same staff can be successively employed on quite different enquiries. This would dispel the spectre of insecurity of employment still the chief obstacle in the way of attracting steady men and women as surveyors.

### Desiderata.

What would constitute a satisfactory minimum programme of housing statistics?

We need information on the following:

(1) *The general physical condition of housing in the country.*

- (a) Number and size of different types of houses (single family houses, two family houses, etc.).
- (b) Age, condition of repair, amenities provided, materials of construction, number of separate dwellings within the structures.

(2) *The socio-economic condition of housing in the country.*
   (a) Measures of overcrowding for various classes of the population (according to their ethnic, economic, occupational, urban, suburban, periurban, rural differentiations) and the amount of "doubling up" of households, including those who are not overcrowded in terms of our standard.
   (b) Rent and travelling expenses in relation to size and amenities of the dwelling paid by the different classes of the population. Relation of rent to total household income.

(3) *The state of the Housing Market.*
   (a) The supply per annum of houses of different type.
   (b) Conversions of houses into flats, demolition rates and rehabilitation of houses.
   (c) Types of tenure, the number of houses owned, the mortgage position, foreclosures.

(4) *Town planning information.*
   (a) Layout of dwellings (situation, row, courts, internal arrangements).
   (b) Land provision, land use, taxation, street plans, open space, zoning plans, transport conditions, social economic and recreational services, community facilities, landscape treatment, etc.
   (c) Social and economic costs to the community of the different townships, housing estates and schemes financed by industrial undertakings. What have been the effects of the policy of suburban development?
   (d) Effect of by-laws, ordinances, rates, etc.

(5) *Public opinion measurements.* ([11])
   (a) Satisfaction or dissatisfaction with present home or features of it. Attitude to neighbourhood.
   (b) Wishes of population with respect to housing. Attitude to ownership.

## Minimum Standards.

We must, naturally, define what we mean by overcrowding. According to our definition, as Sir E. Simon has pointed out, our estimate of the need can differ in the ratio of 400 to 1.([12]) The British Housing Act of 1935 laid down a standard, but in 1939 the British Ministry of Health raised its standard so that 68 per cent. more houses were condemned as unfit for habitation.([13]) ([14])

Biological and social minima must be arrived at. Well-being does not only depend on the amount of air and space available to the occupant. A good beginning to establish such standards have been made in America.([15])

It need hardly be said that if a minimum based on man's physiological need is once accepted no deviation can be per-

mitted. The non-Europeans must get equal treatment. Only on the social side should some variations be made. In view of prevailing racial attitudes a white worker's family should not be expected to eat in the kitchen, as is customary in Europe, if a non-European servant also eats there. In the case of the coloured or native a kitchen could be counted as a living-room, but not in the case of Europeans. Allowance should also be made for time that is spent out of doors according to climatic and economic conditions. In respect to sanitation, ventilation, light, safety, humidity, etc., no difference can be made between the different ethnic groups of the population.

### The Demographic Factor.

It is no good taking the number of families given in the census. "Census families" are a statistical artefact defined as a group of people occupying one dwelling with one food bill; this does not take account of families who lived "doubled up." (Even so acute an observer as Sir Ernest Simon[12]) missed this point.) The 1931 census of England and Wales used three indices to assess the number of genuine families.

(i) The total number of married women of all ages;
(ii) the total number of married women of all ages plus the widowed of both sexes under 65 years; and
(iii) the total number of married women of all ages plus the widowed women under 65, plus 10 per cent. of the single persons of both sexes between the ages of 20 and 54 [16])

Another interesting calculation has been made by Stolper.[17]) Houses must meet the demands of small and large families. Some English writers complain that the new housing estates there do not cater for families without children.[18])

### Migration.

Additional accommodation may be needed without any increase having occurred in the number or size of families. Population shifts following the dictates of the labour market, create a demand in new centres of employment. Much war housing was necessitated in Britain in the execution of armament plans in protected areas. If the Union is to see a brisk period of industrialisation there is bound to be a good measure of internal migration, though a careful location of new industries could minimise this One of the awkward features of internal migration lies in the fact that it need not always lead to the vacation of houses in the area abandoned by the wage earners. Youths and husbands often live away from the rest of their families without that the latter give up any room space. The size of the floating population necessitates a duplication of accommodation requirements and is particularly formidable with respect to sections of our Bantu peoples, unstabilised in the towns or reserves. If planning is to be based on reliable estimates more information about internal migration is needed, especially of our non-European population.

### THE ECONOMIC FACTOR.

To build houses beyond the reach of the poorer sections of the population may lead to gluts in the midst of dire needs. This situation arose in Holland, where demand could not become effective because of the high rents. In England enough houses were built in the thirties to meet the calculated numerical requirements, but, unfortunately, a large part of the population on account of their low wage earning capacity, could not avail themselves of the accommodation provided. It must be realised that in the Union, many are unable to afford even sub-economic rents.[19] Large economies must be effected. A reorganisation of the building industry is overdue. It is remarkable that to-day building is still in the pre-mass production stage of the eighteenth century.[20]

### HOUSING STATISTICS.

Unfortunately, no official information exists about private building activity in the Union, how it is affected by public building, monetary policy, alternate investment opportunities, wage agreements, or the trade cycle. The reports of the Central Housing Board are entirely devoted to the examination of State-aided building. Per contra, the half-yearly reports on housing by the British Ministry of Health are a model of clarity and usefulness, setting out in simple tables the number of houses provided by the different agencies, action taken in the clearance of slums, the number of people rehoused, and the amount of reconditioning which is going on.

Under this heading fall also the formulation of proper definitions of the statistical units used. At first sight enumeration seems to offer no difficulties. But this is not so. For instance, buildings can be classified either according to qualitative criteria, i.e. the presence or absence of certain features in the building or arrangement of rooms, or according to quantitative measurements, i.e. the size, value, durability, density of occupation, number of rooms, height of building, window space, etc. Which is the better yardstick? Should we calculate the intended or the actual use made of premises? Should we also include rooms actually used for business purposes? Some assistance has been given by the International Labour Organisation and the League of Nations in connexion with the international comparability of housing statistics. They define:

1. *The Dwelling.*

" Dwelling should comprise any structurally separated room or suite of rooms in permanent buildings used or intended for habitation by family households and having a separate access to a street or to a common passage or stairway. Detached rooms for habitation which are clearly intended as part of the dwelling should be counted as part of the dwelling."[21]

But this does not give directions how to group boarding houses, or rooms, inhabited by separate lodgers, but not leading on to a corridor or stairway. Incidentally, dwelling and house are used synonymously in the Union census since 1926.

II. *The Room.*

> " A room is any space larger than 4 square metres enclosed by walls . . . as however the proportions of a room are no less important than its superficial area, the Committee adopted as an additional test its capacity to contain a bed for an adult, such specification being regarded as the simplest way of describing the proportions of a room."

In other words narrow corridors are excluded, a room " must be able to contain the bed of an adult and the walls also must reach to the ceiling." It is a matter for discussion whether stoeps and sleeping porches should be included as rooms. Subsidiary rooms are sometimes counted as half units. The " kitchen " will be differently interpreted according to social class and race; it should be enumerated separately as it is of cardinal importance to the housewife.

III. *Household.*

> " The household is defined as a group of persons who together organise their domestic life separately from other persons."

This includes domestic servants and boarders but excludes lodgers not boarding with the household, who form a separate household. We must distinguish between family households and the very much smaller number of non-family households, i.e. people living in hotels, institutions, military barracks, caravans, camps, boats, schools, etc. A border-line case exists where the number of lodgers boarding exceeds the number of family members, inclusive of servants. Directors and staff of institutions, hotels, etc., occupying separate dwellings should be counted as family households.

IV. *The Occupant.*

We make allowance for the differential age by counting " equivalent persons," a person over ten years equals one unit, below that age half a unit. Infants are not counted at all. The count of occupants should be a *de jure* one rather than *de facto* enumeration.

## Housing Exchanges.

Statistical investigations are relatively cumbersome and time-consuming. For planning purposes they have the disadvantage of being soon out of date. In order to keep current statistics we would suggest the organisation of Housing Exchanges in different centres of the Union. These Exchanges, organised like employment exchanges, could keep records of vacant buildings. The number of vacant buildings is

a good index of the state of the Market generally. The public would be encouraged to notify the exchanges which would mean a reduction in the time in which dwellings remain unoccupied, a factor making for rent reduction, convenient to landlords and tenants. Estate agents would probably not be seriously affected by the establishment of such exchanges since they cater more for the middle class, nevertheless, they could be brought into such a scheme.

## Community Planning.

" No man is an Iland, intire to it selfe; every man is a peece of the Continent, a part of the maine."

Just as the individual needs can be assessed correctly via his family needs, so it is wise not to consider the individual family in isolation from the community with which it is interrelated. The value of dwelling is a function not only of the external structure but also of communal conditions. Outside and inside of houses must be taken as one whole. Only the relation between the outer conditions and the home itself gives an accurate conception of the way in which people are living or can live.([6a]) It is for this reason that we have included town planning queries in the list of desiderata. Neglect of the neighbourhood values has created many social problems in the new housing estates.

Spaciousness has its inconvenience too. Neighbours are not so handy or so obviously neighbours at all, and many friendly and exhilarating quarrels must be dispensed with. A slum can be smoky, unhealthy and drab and yet have a soul which a brand new place lacks.

This comes out clearly in the excellent survey of Birmingham made by the Bournville Village Trust:

> " First to emerge from the statistics is the upheaval caused in the common daily round of simple folk by removal to a new estate. For example, anywhere in the crowded centre of a city a woman can pop out of her home and find, a few doors off in a dwelling similar to her own that has been made into a little shop, the common commodities that are her daily need. Where will she find like facilities in a municipal housing estate? And the little shopkeeper behind the counter set up in his little parlour—where will he find a chance to drive his small trade in the grand new place.
>
> " It is no good dismissing such small considerations as too pettifogging to be taken into any reckoning of this great problem, because it is just such small factors that decide the fate of great enterprise. To add another instance, it is useless to erect grand blocks of flats if the people whom you have in mind as tenants want gardens, sheds and a chance to keep live pets.

"In dealing with human affairs one finds what people ought to like is not always the same thing as what they do like."(22)

The human element must be a feature of our planning, if planning is not to equal totalitarianism. It is not enough to resettle people in new houses. They must be assisted to form a new community. It is not enough to have low rents if new houses mean new expenses, new curtains, more furniture and new clothes. Only broad vision will solve the problems awaiting the planner.

## Conclusions.

After this war is over and the Giant of Greed defeated, we shall have to make war on another monster, the Giant of Need. Added to a scarcity of all factors of production there will be an inelasticity of consumption. The scissor effect can be overcome only by early and adequate planning.

This war on bad housing demands a strategy like any other great undertaking. How can the efficiency of the building industry be increased? Have we to upset established relations between white skilled and black unskilled workers? Should priority be given to the poorest, the non-Europeans where the need is greatest? How is the public to be educated to make use of the facilities provided? What quality is considered as minimal, taking into consideration the need for quantity? If we are not to let the issue deteriorate into a dog-fight of partisan organisations we must raise the discussion on to a level of factual and rational enquiry.

What does this mean? We must bring together all the scattered experiences and ideas of qualified workers. They must be given body by broad surveys designed to supply information commensurable with the magnitude, importance and complexity of the decisions to be taken. The following steps are therefore indicated:

(1) The calling of a National Convention of officials, welfare workers, builders, social scientists, etc., which would pool existing information and assess the personnel available to gather new data and analyse it.

(2) From this Convention a National Advisory Committee could be selected able to assist the Government on broad issues of policy and especially consider the legislative, financial and social aspects. This would leave the Central Housing Board with the job of instigating and supervising the execution of local plans.

(3) Simultaneously national surveys, making quantitative studies at least in selected sample areas of the numerical need, public opinion and town planning problems, should proceed with all vigour.

(4) As soon as some idea is gained of the magnitude of the demand, the supply situation should be tackled by making plans for the expansion of the building industry, its reorganisa-

tion and rationalisation, and for discussion with all the diffeient parties concerned.

(5) The public should have the fullest opportunity of familiarising itself with all facets of the problem. A matter so close to the hearts of the people as housing cannot be effectively planned if the ordinary man does not express his own wishes in the matter. On the other hand the natural scientist, sociologist and economist must arrive at minimum standards, together with workable schemes for the realisation ot the ascertained biological and social requirements.

If the country will give proof of as much determination and goodwill in the prosecution of reconstruction planning as it has shown on behalf of the war effort, South Africa can this time promise her soldiers " homes fit for heroes to live in."

## REFERENCES.


(1) U.G. No. 9 (1943), p. 3, *passim*.

(2) Gray, J. L.: " High Rents as a Contributory Cause of Malnutrition among Urban Europeans." *Race Relations* VI., No. 3, p. 118-120.

(3) Barnes, H.: Housing (1923).

(4) Elsas, M. J.: Housing before and after the War (1942), p. 43.

(5) U.G. No. 9 (1943), p. 4.

(6) Aronovici, C.: Housing the Masses (1936), pp. 224, 244.

(6a) *Ibid.*: *Ibid.* p. 261-2.

(7) League of Nations Econ. Intelligence Service: Urban and Rural Housing (1939), p. 16.

(8) U.G. No. 33 (1939), p. 10, par. 3.

(9) *Ibid*, par. 8.

(10) *Ibid*, par. 1.

(11) Mass Observation: An Enquiry into People's Homes (1943).

(12) Simon, Sir E.: The Anti-Slum Campaign (1933).
P.E.P.: Housing England (1934). (This report contains an interesting table of different estimates made between 1920-1934 of housing requirements and methods used.)

(13) Balfour, Lord: " Overcrowding—a Bad Bill." *Contemporary Review* (March, 1935).

(14) " Housing in Britain." *The Economist* (24th April, 1937).

(15) Am. Public Health Assn.: Basic Principles of Healthful Housing (1939).

(16) Census of England and Wales (1931): Housing Report.

(17) Stolper, W. F.: " British Monetary Policy and the Housing Boom." *Am.Quart.J.ofEcon.*, LVI (November, 1941).

(18) Williams, N.: Population Problems of New Estates with specific reference to Norris Green (1939).

(19) Brinton, W.: " Slums and Housing " in the Official Report of the Social Survey Conference, Cape Town (1942).

(20) Perry, C. A.: Housing for the Machine Age (1939).

(21) League of Nations Econ. Intelligence Service: Housing Statistics (1939).

(22) Bournville Village Trust Research Publication: When we build again (1941), p. 95.

South African Journal of Science, *Vol. XL, pp. 372-378, November, 1943.*

# "WINE, WOMEN AND SONG."

## The Story of Cape Town's First Academy of Music.

BY

Percival R. Kirby,

*With 1 Photograph.*

*Read 28th June, 1943.*

Many books have been written about the early days of Cape Town, and I dare say that most of my hearers are familiar with some, at least, of the curious things that have happened there in days gone by. But by no means all of them have yet been described; and I have often felt the urge myself to write yet another book about some of the strange happenings that took place in our Mother City in days gone by which seem to have escaped the eagle eye of most of our historians. And it is of one of these that I propose to speak in this paper.

I have given my story the rather unusual title of "Wine, Women and Song" for a number of reasons which you will yourselves discover as I unfold my tale. The tale itself is the story of the founding of what I believe was one of the earliest, if not the very earliest, of the academies of music to be founded in South Africa.

Now, although there was a considerable amount of musical instruction given at the Cape during the eighteenth and the early years of the nineteenth centuries, nothing of a systematic nature appears to have been embarked upon until the following events took place.

In the early part of the year 1814 a new organ, destined for the Lutheran Church in Strand Street, was landed at the Cape (1). With it came a young organ-builder, named Edward Knollys Green—E. K. Green (2)—who had been sent out from England to instal it. Young Green was just twenty-one years of age, and full of youthful enthusiasm; and after he had completed his work and installed the new organ successfully, he had made himself so much at home that he determined to stay in Cape Town, and to open a shop as a music-seller.

This he did, and his new store was at No. 45 Bree Street, where the Prince of Wales' Hotel stands to-day. Like other music-dealers at the Cape, Green sold music and musical instruments, and also occasional "side-lines." But, being something of an organist, he added to his income by acting as organist to the Paarl Church, of which he was the only English official. For his services as organist Green received the handsome annual salary of fifteen pounds, and for this he used to ride on horseback from Cape Town to Paarl on the Saturday afternoon, play the organ at the Sunday service, and ride back again in time

to open his shop again on Monday morning. And I have not the least doubt that, as he was a good business man, he got the contract to repair and to tune the Paarl organ.

Before long young Edward Green had lost his heart to a young lady of Cape Town—a Miss Berning—and the pair were married. It was the son of this couple who founded the famous wine business associated with the name of E. K. Green. But that, unfortunately, is by the way; though it goes some distance in justifying my title " Wine, Women and Song."

In 1824 Green secured the contract for installing the organ in the Groote Kerk in Adderley Street, but he died before he could complete the work. His widow, however, was allowed to finish the job.

Now at about the same time that he secured this important contract, Green determined to enlarge the scope of his business by running a music-school in conjunction with it, and to this end he had been in correspondence with a young musician in England whom he doubtless had known before he himself left for the Cape in 1814. This young musician was named Frederick Logier, and he was the son of a man who had practically set Europe by the ears on account of his revolutionary ideas regarding the teaching of music.

For Johann Bernhard Logier, who had been born at Cassel in 1777, and who had come to England in 1790, had married the daughter of the famous bandmaster and clarinet player, Willman, and, when a daughter was born to the couple, Logier had devised a completely new system of teaching music especially for the instruction of his own little one, and his system had become so popular and so profitable that it had divided the musicians of Europe into two camps.

Those of you who are curious can learn much of what happened by looking up Grove's Dictionary of Music and Musicians under the name Logier (3); and if you do, you will be able to form some idea of the effect that the introduction of this new method had upon the music-teachers and citizens of Cape Town.

What was this new and revolutionary system?

Well, to begin with, Johann Bernhard Logier had invented a mechanical device, called the " Royal Chiroplast," for ensuring that his young pupils might readily acquire a correct position of their hands upon the pianoforte keyboard, and he had patented it in 1814 (4). The Chiroplast seems to have been the earliest mechanical appliance ever invented for this particular purpose.

In addition to devising this machine, Logier had made a minute analysis of the teaching of musical rudiments and of harmony, finally writing a very comprehensive and thoroughly rational text-book of Thoroughbass, or Harmony, which soon came into general use, and which is still to be met with to-day. And it is worth noting that this was the first text-book on the subject used by Richard Wagner in 1828 to teach himself harmony (3).

MR. AND MRS. FREDERICK LOGIER
From a photograph in the possession of Capt M. Green, Plumstead.

But Logier's personal teaching went far beyond his mechanical inventions and his text-books, and so popular did he himself become that he found it necessary to teach his pupils in classes, even on the pianoforte, thus anticipating by a century some of our present-day teachers who think their methods so new and so modern. Logier frequently taught as many as twelve pupils at a time, each playing upon his or her own pianoforte ([4]).

His success was so great that he began to attract the attention of thé Prussian Government, which sent a musician, Franz

Stoepel, to London in 1821, to report on his work; and Stoepel's report was so enthusiastic that Logier was invited to come to Berlin and to establish a school there, where he should teach twenty German musicians his method, with a view to spreading it over the whole of Prussia [4]. During his stay in Germany Logier spent part of his time in Dresden, where he had as one of his pupils the daughter of Dr. Henry Lichtenstein, who, it will be remembered, had visited the Cape himself in the early years of the nineteenth century [5].

The opinion of Continental musicians was divided on Logier's system. Mendelssohn, for example, derided it, calling it "teaching by steam" [5]. But Spohr, who took the trouble to examine it personally with minute care, was enthusiastic, especially over the harmony teaching. He actually visited Logier's classes when in London, and wrote a melody for the children to harmonise, promising that he would print the best solution in his own memoirs. And he kept his promise, too; for the harmonisation of that melody, by a tiny little girl, appears in his autobiography [6].

It was, then, the son of this man, trained in his father's methods, who had been invited to come out to the Cape to start a School of Music there.

Young Frederick Logier arrived in the English Brig, the "Luna," on 26th February, 1826, and on 3rd March there appeared in the "Cape Town Gazette and African Advertiser" a notice to the effect that "E. K. Green is now happy to announce to his friends and the public that Mr. F. Logier has arrived from London, for the purpose in conjunction with himself of opening an Academy, on his father's system, for pianoforte playing and the theory of music." And the notice went on to say that "Mr. F. Logier will undertake to instruct a limited number of pupils on the violin, violoncello, flute and French horn" [7].

Another advertisement, which appeared on 29th March [8], informed the public that the charge for tuition amounted to sixty rix-dollars (about £4 10s.) per quarter, payable in advance. The same advertisement gave in detail the "Regulations of the Academy," which were as follows:—

> "A Suite of Commodious Rooms is appropriated to the use of the Pupils. In one are several Instruments for simultaneous performance; here, also, the Pupils receive Lectures upon, and write Exercises in, Harmony.
>
> "Each Class will meet twice a week, two hours each lesson; one of which will be occupied in receiving Individual Instruction on the Pianoforte and writing Exercises, the other in Lectures on the Principles of Harmony, and occasionally playing in Concert.
>
> "Mondays and Wednesdays, Tuesdays and Thursdays, will be the days fixed for Ladies' Classes, Fridays and Saturdays for Gentlemen."

So my readers will realise that then, as now, it was the fair sex that was chiefly expected to take a practical interest in the art of music; and I think that this fact further justifies my title! But let me continue with the regulations of the new Academy:—

"Each Class," they said, "not to be composed of more than six pupils.

"Hours of the Classes will be from 8.0 o'clock until 10.0, from 10.0 to 12.0, from 12.0 to 2.0, and from 2.0 to 4.0 o'clock each day."

One wonders when poor Logier ever took his lunch; but perhaps he employed an assistant to carry on while he snatched a hasty bite! The Regulations continue, however:—

"Any lesson lost in consequence of non-attendance at the proper Class hour, may be regained by the Pupil's attendance with one of the other Classes.

"A Parent or Female Friend is allowed to accompany a Pupil to any of the Lectures.

"No extra charge is made for the use of Piano Fortes, Chiroplasts, Lecture Board, etc., etc., in the Academy; but should a Chiroplast or Hand Director be necessary for a Pupil to practise with when at home, such may either be purchased by the Parents, or hired from Messrs. Green and Logier at 5 Rds. per month, so long as it may be required.

"Charge will be made for Music, Blank-book and Slates."

And now comes a very extraordinary thing, the list of composers whose works are to be studied by the pupils; extraordinary for two reasons, firstly because it is so comprehensive and serious, and, secondly, because it is headed by the name of a composer which one would never have expected to see at such an early date—John Sebastian Bach!

"The Course of Study," say the Regulations, "to consist of Mr. Logier's Elementary Books, and a selection from the works of the most classical authors, ancient and modern, viz., S. Bach, Corelli, Handel, Scarlatti, Haydn, Mozart, Clementi, Cramer, Dussek, etc.; after passing through this course, the whole range of musical authors will be left open to the choice of the student."

Without doubt this was a very excellent syllabus. But you may ask why the name of Beethoven was not included? Well, he was still alive in 1826, and was by many regarded as an ultramodern, much as many musicians of to-day regard Schoenberg and his disciples, not to mention still more recent names.

Nevertheless, the name of Beethoven was not unknown at the Cape in those days, as we shall see in a moment.

The Academy actually opened on Monday, 3rd March, and soon excited considerable interest among the citizens of Cape Town.

In the meantime, the senior partner of the firm, if I may so style it, who was E. K. Green himself, kept on advertising

his wares in the local Press, and informed the public that, in addition to stocking " Elegant and Plain Piano Fortes " and " Upright Cabinets, a Chamber Organ, English and Spanish Guitars, Violins, Flutes and Clarionets . . . Kent Bugles, Cavalry and Concert Trumpets, Ladies' Tambourines, Double and Single Flageolets, and all kinds of Military Instruments," he had " likewise received from Messrs. Price and Gosnell, London, a well-assorted consignment of Perfumery," which would be sold at moderate prices ([9]). Apparently the name of Green was early destined to be associated with alcohol.

I have already suggested that the name of Beethoven was not unknown in Cape Town even in 1826, and this was so. A short paragraph, which I strongly suspect was written by Logier, although I cannot prove this, appeared in the " Advertiser " on 9th June. It was entitled, " Beethoven, the Celebrated Composer." It is of particular interest, seeing that Beethoven was still living. Here it is:—

> " Though not an old man, he is lost to society, in consequence of his extreme deafness. His features are strong and prominent; his eye is full of rude energy; his hair, which neither comb nor scissors seem to have visited for years, overshadows his brow in a quantity and confusion to which only the snakes round a Gorgon's head offer a parallel. He has always a small paper book with him, in which he jots down any musical idea that strikes him. The moment he is seated at the piano, he is evidently unconscious that there is anything in existence but himself and the instrument; and, considering how deaf he is, it seems impossible that he should hear all he plays. Accordingly, when playing the piano, he often does not bring out a single note. He hears it himself in the " mind's ear "; while his eyes, and the almost imperceptible motion of his fingers, show that he is following out the strain in his own soul through all its gradations. The instrument is actually as dumb as the musician is deaf " ([10]).

Logier's success as a music-teacher in Cape Town unfortunately sowed the seeds of discord among others of the profession, just as that of his father had done in Europe, and before long acrimonious letters and trenchant criticisms began to appear in the papers ([11]). Other writers, however, took up the cudgels in his defence, and he himself, as his father had done before him, organised a public examination of his pupils (doubtless the first ever held in South Africa) in order that the citizens of Cape Town might judge for themselves. To this end he engaged the hall of the Commercial Exchange, which stood on the site now occupied by the Old Post Office Buildings ([12]). Apparently this move was a great success, for the examination was attended by a " numerous company," and proved, so a correspondent said, " that in the opinion of those who are the best judges, Mr. Logier is considered to be a valuable acquisition to this Colony " ([13]).

Before long, Logier opened a singing class, in addition to his other work, and his establishment seems to have developed and continued with success ([14]). But soon other teachers, with other methods, which, if not so serious or efficient, may have been more attractive to the young people of the Cape, began to distract attention from Logier's Academy. One of these was the celebrated Boniface, whose Gallic wit and beribboned guitars seem to have attracted almost more than their fair share of attention. But the story of Boniface I must leave for a future occasion.

Frederick Logier remained, however, in Cape Town. For him fashions did not change, for he was a serious and earnest musician, and he remained to the end, as he styled himself, a "Professor of Music."

He married Miss Anna Berning, thus consolidating his friendship with the Green family, and maintained the practice of his art until the day of his death, which occurred in 1867. He had been a citizen and musician of Cape Town for forty-one years.

His tombstone may still be seen in Maitland Road Cemetery No. 1, where it stands upon the plot belonging to the Green family. The inscription upon it completes our knowledge of the man and of his wife, for it runs as follows:—

> "Frederick Logier, Professor of Music. Born in County Cavan, Ireland, 25th April, 1801. Died at Cape Town, 12th October, 1867.
>
> "Anna Elizabeth Berning, Relict of the above. Born 2nd September, 1784. Died 18th June, 1868." ([15])

## REFERENCES.


(1) McINTYRE, D. G. : Early Organs and Organists at the Cape. Cape Town, p. 7 (pages un-numbered) (1934).

(2) Details of E. K. Green's early life at the Cape were given to me by Captain Maurice Green, of Cape Town.

(3) GROVE, G.: Dictionary of Music and Musicians. London, **2:** p. 766 (1919).

(4) GROVE, G.: Dictionary of Music and Musicians. London, **1:** pp. 346-7 (1879). (This article has been dropped in later editions).

(5) COX, H. B. and COX, C. L. E.: Leaves from the Journals of Sir George Smart, London, p. 171 (1907).

(6) SPOHR, L.: Autobiography. London, **2:** pp. 98-100 (1865).

(7) *The Cape Town Gazette, and African Advertiser,* **21:** No. 1051, p. 2 (1826).

(8) *The South African Commercial Advertiser,* **2:** No. 13, p. 1 (1826).

(9) *Ibid.*, **2:** No. 21, p. 1 (1826).

(10) *Ibid.*, **2:** No. 23, p. 3 (1826).

(11) *Ibid.*, **2:** No. 52, p. 3; No. 56, p. 2; and No. 59, p. 1 (1826).

(12) *Ibid.*, **2:** No. 54, p. 1 (1826).

(13) *Ibid.*, **2:** No. 56, p. 2 (1826).

(14) *Ibid.*, **2:** No. 67, p. 1 (1826).

(15) Details supplied to me by Mr. A. C. H. Key, Secretary to the Cape Peninsula Cemeteries' Board of Trustees.

South African Journal of Science, *Vol. XL, pp. 379-389, November, 1943.*

# EVENING DISCOURSE.

## GEOLOGY IN WAR AND AFTER

BY
Dr. S. H. Haughton,
*Director of the Geological Survey, and Controller of Non-ferrous Materials.*

*Read 29th June, 1943.*

In discussing any subject it is usual to define the terms one proposes to use. The first term in my title—" Geology "—may be defined as that science which has for its object the study of the earth and of the various constituents which go to form the earth; the human beings who follow that science are called " geologists." " War " is more difficult to define as tersely, since the concept of it has varied from age to age. As we are experiencing it to-day, however, it is probably near the truth to say that war is a combat between two groups of nations, in which all the physical, mental and moral resources of the one group are arrayed against those of the other group in an attempt to achieve ultimate and complete victory by force of arms, such victory being desired in order that the accepted mode of human life of the one group may, in consequence, become the mode of life of the other. Such a definition, to be thoroughly understood, involves the desirability of further definition of some of the terms used within it; but as my theme this evening is geology rather than war, I propose to leave further comment on the definition of war to the philosophers, merely stressing here that part of it that refers to the mobilisation of all the physical, mental and moral resources of the combatants. Being no seer, I cannot define the final word of my title. What will come " after " we cannot say; but, as far as our side of the present struggle is concerned, I accept that the rough outline of the picture of the world that is to be was drawn for us by the framers of the " Atlantic Charter."

Geology is a young science. War is as old as the human race. But war, throughout the ages, has been progressively scientific and, in this present struggle, scientific knowledge is being mobilised and brought to help the contending groups to a far greater extent than has ever happened in the past. Nevertheless, I do not think that those who have called science to their assistance have as yet realised that those who practise in life as geologists could be of greater help than they are at present. This may be the fault of the geologists themselves, for they are a retiring body of men who are even to-day pictured by many as long-bearded professorial individuals, spending their

days and nights poring over the mysteries of a fossil bone or gazing down a microscope tube at fragments of rock brought from some far-distant land. Bret Harte's description is still accepted in some quarters as being a true picture of a meeting of these very learned people.

At the same time, there still appear to exist in certain quarters responsible for certain phases of the military struggle men who consider that geology is too young a science to be conscripted for service, and that its much younger sister science, geophysics, should be confined to the nursery. As a result, we have seen published photographs of men in uniform scouring the desert with forked sticks seeking those water supplies on which the lives of thousands of troops will depend; and, in imagination, one can hear the authority who gave these "diviners" their orders saying "What was good enough for Moses is good enough for me. I don't believe in your new-fangled ideas about dip and strike or porosity or magnetic and electrical anomalies."

I think, however, it would be of interest, despite this longevity of Mosaic practice, to consider in what various ways, if any, those who study the earth and its various constituents could be of value in the prosecution of an "all-in" war, and then to ask ourselves (without giving an answer here and now) in how many of these ways the geologist has been asked to assist or in how many he has sought to assist.

It is clear that war demands, in an ever-increasing measure, armaments and yet more armaments, and that these in turn require greater and greater quantities of metals and mineral products whose only source is the earth. In times of peace, the geologist pays attention to the nature, mode of occurrence and location of mineral resources and even assists, as far as he is permitted, in their development when they are developed. In war, and particularly in the present war, every combatant nation finds itself faced with the necessity both of stepping up production from sources already producing and of discovering and opening up new sources of supply, particularly when the chances of battle deny to it resources which it has previously enjoyed. In such a task, the geologist can take an important part; and among the Allied Nations, geologists have been mobilised, to a greater or less extent, to this end with varying degrees of success. Naturally, the State geological organisations have been accorded the greater share in such work; and it may be of interest to cite one or two instances of the success which has attended their efforts, culled from published information in the British and American technical press.

In Great Britain, the Geological Survey was highly praised by the Ministry of Works for the help which its geologists gave in the problem of the excavation of outcrop coal to increase coal output, an urgent national problem. The Survey was, in fact, requested to pass from the role of consultant to that of

co-leader in the planning of this national effort which, in 1942, produced more than a million tons of outcrop coal. Development of felspar in the Hebrides, advised by the Survey, enabled the United Kingdom to become absolutely independent of outside sources of supply. Intensive study of iron ores, tin, wolfram, lead, zinc, fluorspar, and barium minerals, added to the knowledge thereof already possessed, enabled acceptable and valuable advice to be given regarding increased production of these essential war minerals.

In the United States which, rich though they are in most minerals, had no pre-war production of certain vital ores, Federal and State geological organisations proved, in 1942, the existence of a major deposit of chrome ore by exploratory work in Montana and discovered vanadium ore in Oregon—to instance only two examples which are of very great value to the steel outlook of the States.

In the Union of Soviet Republics, of course, all geological work is State-directed; and the phenomenal increase of mineral output and in the number of known mineral deposits which was primarily due to the work of Russian geologists before the war leaves no room for doubt that these geologists have been employed successfully during the war in similar productive work.

Our own country has seen the Geological Survey turned into a body whose energies are devoted almost entirely to the investigation of those mineral deposits which can prove of value to our war effort and it is possible to say, without unbecoming immodesty, that its efforts have not been unattended by a certain modicum of success.

Although iron, manganese, chrome, tungsten, tin and a host of other metals and non-metals, together with oil and coal, are essential to the prosecution of war in its modern guise, there is one mineral substance without which war cannot be waged. This is water; and the exigencies of global war demand that water must often be obtained and used in places where it had not previously been required and in quantities sufficient to maintain large numbers of men and of machines. Dr. E. B. Bailey, Director of the Geological Survey of Great Britain, has written that, in his opinion, the investigation of, and advice concerning, underground water remain the most important contribution that his Department is making to the war effort. Our own Defence Department recognised the part that water supplies would play in the campaigns in East Africa and North Africa and, in addition to equipping boring companies with the necessary staff and equipment for tapping underground water supplies in the desert, formed and equipped, with a nucleus of Geological Survey experts, a special Geological and Geophysical Section of the Engineers to locate sites at which boring should take place. The success attending these efforts has been officially recognised in despatches.

There is, however, another side to the picture, a side which shows that, although in a number of military engineering

matters the assistance of the geologist could legitimately have been invoked, the utilisation of geological knowledge has either been entirely neglected or has been singularly haphazard. As Professor P. G. H. Boswell pointed out in his Presidential Address to the Geological Society of London, the fundamental reason for such haphazard utilisation of geological knowledge is the lack of awareness on the part of the general public (and he might well have included the majority of politicians, soldiers and high-ranking public servants) of the content of the science. Most of these people probably more or less vaguely associate geology with a study of rocks or of minerals or of fossils, and some of them are probably aware that the geologist professes to have some knowledge of underground water; but few of them would do other than express incredulous surprise if told that geological science could have anything useful to say on such subjects as the strength of rock or subsoil foundations for fortifications, gun emplacements or other surface structures, on the drainage properties of soils, on the ability of airport foundations to withstand landing shock or their reaction to explosives, or the location and construction of air-raid shelters or tunnels. Yet to these and numerous other war-time engineering problems geology can contribute its quota of knowledge. When it does not, costly mistakes may be made as in the British instance where a sum approaching half a million pounds was wasted at one aerodrome site alone. I have been told that, in a salt-encrusted semi-desert area, the cohesion of the surface of a proposed landing-ground was tested—in the dry season—by the simple method of banging the heel of a boot (of course, with the foot inside) on the surface. The inspecting officer pronounced the result satisfactory! One can only hope that there will be neither rain nor dew there, at least until the end of the war.

It must not, of course, be assumed that every man who calls himself a geologist is capable of advising on all of these and cognate matters which fall to be dealt with at some time or other by military authorities; but it is safe to say that from some geologist or another it is possible to obtain valuable advice on one or other of the problems after he has examined them in the light of the principles of the science which he professes. Modern war, as has been well said by S. Paige, the Senior Geologist to one of the Divisions of the United States Army Engineers, is in its own right an engineering enterprise on a scale so vast that it dwarfs any other field of organised human effort, as well as being a social co-operative undertaking. The problem which faces those responsible for controlling such undertaking is to utilise most effectively all appropriate technical data where and when necessary. I submit that the data furnished by geological knowledge are basic and fundamental to any war effort; those possessing that knowledge should be given the right and the opportunity to apply it to every problem which, in its nature, demands such application.

I should like to make it clear that, in hinting that geological knowledge may not have been utilised in this war to the extent that it might have been, I am not for a moment suggesting that it alone could win a war; nor do I think that geologists or any other body of professional men will help the war to a successful conclusion by assuming potentialities which they do not in reality possess. It is, however, correct to say that neglect to utilise in the proper place and proper manner such information as geologists as a body possess might well be a contributory factor to losing battles and even to losing the war.

## II

I come now to the second part of my subject—the rôle of geology after the war; and here we can only " see in a glass darkly " and our mental retinas may receive a very distorted view.

The science of geology is both a field of research and investigation and one of the tools of industry. Like all sciences it has its " pure " and " applied " facets, the boundary between which it is sometimes difficult to discern. Industry is slowly becoming increasingly conscious of the usefulness of this particular " tool " without, I fear, knowing exactly how it works or what is its proper function; sometimes the tool is expected to perform a task for which it was not designed and, when it fails to do this, or does it inefficiently, it is condemned as being valueless for all purposes; sometimes it is given credit for more than it does perform as in the case of the old lady who expressed her unbounded admiration for geologists for their infallibility in knowing exactly where to put petrol bowsers. Further, when the professors of the science are working purely in the field of research, they are apt to be considered by the " practical " man as eccentric but harmless individuals far removed from his august consideration.

Professor Boswell, as has already been mentioned, has drawn attention to the " lack of awareness " on the part of the general public of the content of geological science. If this lack of awareness is to disappear after the war, it is clear that the science ought to become an integral part of the curricula of our post-war schools and colleges and that the coming generation should become as familiar with its fundamentals as is the present generation with certain other branches of knowledge, such as the names and features of film stars.

It is, of course, true that geology forms one of the subjects of instruction at our colleges and universities and even at some of our schools; but all too often it is a subject treated both by students and teachers as one for examination purposes and not as one intended as " a study of the earth." The multiplicity of facts that have accumulated since first the earth began to be studied scientifically has created a tendency to split the science into a number of separate sub-divisions, each of which

is treated more or less as a separate entity in our teaching institutions. Moreover, the beginner is too often forced to consider the less interesting sub-divisions, such as the proper identification of the so-called "common" minerals or "common" rocks from laboratory specimens (which may or may not be properly identifiable) and the text-book facts and definitions of physical geology. In the "practical" course in the laboratory, the same beginner experiments with blowpipe, platinum wire, and reagents on the same "common" minerals and all too frequently decides that "if this is geology, I'm going to study something else." A few stalwarts annually decide to overcome the initial obstacles and to continue with the subject to the end of their University careers, emerging thereafter with sufficient theoretical equipment and laboratory experience to enable them to begin the study of the earth in the field and ultimately to have the right to call themselves "geologists."

Under such circumstances it is no wonder that the public lacks an awareness of the content of geological science; and I suggest that, as mankind is so absolutely dependent upon the earth and upon the fruits thereof, one of our aims should be to inculcate, in the post-war world, as complete and universal an understanding of the earth and its nature as is possible. Discussion regarding the means whereby this aim can best be attained may well be left to the educationists who are responsible for the curricula of our schools and colleges.

Assuming, however, that the post-war world is more fully aware of the content of geological science, we must then ask what is to be the future rôle of our science in that world.

The enormous destruction of the mineral products of the earth and of the materials made from them during the war will demand enormous replacement in the period of reconstruction. Mineral deposits are in their very nature irreplaceable. Before and during the war production has taken place at unprecedented rates, and some at least of the present productive deposits will probably be exhausted before the post-war demand can be fully met. Either, therefore, new deposits will have to be discovered and opened up or substitutes will have to take the place of unprocurable mineral materials. The demand for minerals may thus exceed the available supply and the world find itself faced with the same problem as faced the leaders and the millions of post-Revolution Russia. In that land, where in order to put into effect the social schemes envisaged by the makers of the "New Order" it was necessary to develop to the maximum possible the capital resources of the Republics, the geologist has, since the Revolution, played his proper part. He has in a planned manner discovered hidden mineral riches, not only in the lands hitherto unexplored but even in and near centres of population long since presumed to have been examined; and, whenever these discovered riches have required to be developed and used for the benefit of the Soviets, the geologist has been

followed by the mining engineer and the mining engineer by the industrial engineer. Others of his discoveries have become the subjects of research in an attempt to find new uses for known materials or to find new methods of treating his finds in order to make them useful.

If it be given the opportunity to do so, I am certain that geological science will be eager to serve the " brave new world " to come in the same manner as it served, and continues to serve, the Union of Soviet Socialist Republics. Africa itself; not omitting that portion of it in which we are more immediately interested, offers a wide scope for detailed geological exploration with a view to the discovery of mineral wealth.

In the first part of this address I suggested that the application of geological knowledge would be of assistance in the consideration of engineering problems; and I should like to think that, after the war, there will be a close co-operation between the geologist and the engineer. Even before the war, there were some outstanding instances of the beneficial results of such co-operation; and it appears to me that it might be of interest if I quoted an example.

For several years before 1928 the United States Congress had considered several projects for building a large dam on the Colorado river at Boulder, but in the year named the critics of the scheme definitely charged that such a dam could not be built. The President of the time thereupon appointed the Colorado River Board to report on the feasibility of building Boulder Dam and appointed to that Board an Army Engineer General as Chairman and two civilian engineers and two geologists as members. Dr. C. P. Berkey, one of the geologist members, has recently written of this as follows: " The Board was appointed to determine whether local conditions indicated that such a structure could or could not be safely built, and if it could, where and how. There are just such vital matters in every individual case. In this one it was necessary to determine whether Black Canyon or Boulder was the more favourable, what particular location was the best, whether the rock formations at that spot were strong enough to carry the load and thrusts of a dam more than 700 feet high, and sound enough to permit safe excavation in the canyon walls of diversion tunnels large enough to care for the river while the dam was building. It was necessary to judge the quality of more than 120 feet of sand-gravel river fill and how this material would behave under excavation. It was even more important to determine whether satisfactory conditions would be encountered in the rock floor beneath. There was question whether the river in the beginning had laid out its course on a fault zone or other earth weakness, and whether there was danger of renewed movement that could endanger the structure. Even though the canyon walls might be strong enough to support such a great dam, were they also impervious enough to prevent the water of the reservoir from leaking out and thus cheating the service

it is expected to give?" These and many other questions had to be answered by this Colorado River Board; and, as a result of their answers, the great Boulder Dam exists to-day. Since the appointment and success of that Board, recognition of the value of the geologist's co-operation with the engineer on such projects has been the rule rather than the exception in the United States, and geological science has been called in to study the problems associated with various types of engineering projects,—dams, bridges, tunnels, subways, skyscrapers, waterworks, highways and other less pretentious works. I think we are justified in submitting that what proved such a success in pre-war times in the United States is worthy of more universal extension after the war. For such an extension to be useful, however, geologists themselves must recognise that their science, in addition to being descriptive and historical and, possibly, somewhat speculative, is also factual, quantitative, and " immensely practical " and that it is these latter features that must be stressed when it is called upon to be immediately harnessed in the service of mankind.

The early leaders of geological thought, and in particular Sir Charles Lyell, taught that it was essential to study the present in order to elucidate the past; and geologists to-day, from their earliest years as such, follow this teaching and study the effects of wind, water, sun and ice upon the rocks, rock-debris and soil on the surface of the earth. These effects have a vital bearing on man's welfare. Here in Southern Africa we are becoming increasingly conscious of this fact. Soil erosion is impoverishing our heritage and certain steps are being taken or are in contemplation in order to combat this wastage of our wealth. To cure a disease it is necessary to know its cause, unless one acts empirically. From a geological point of view, the causes of soil erosion are many; but among them are certain " Laws of Nature," certain natural forces well known to geological science. Untamed, these laws would prove our undoing; our task, therefore, is rather to harness such natural forces and to make them our servants than to attempt the impossible task of changing them. The struggle to accomplish this will be a continuing one and will demand the mobilisation of much thought and skill. In this struggle the geologist can and should play his humble part.

There is also a relationship between the sciences of geology and medicine. As recently as February of this year, the Geological Society of London—the premier Geological Society of the world—held a symposium on " Some medico-geological problems." Two problems that received particular attention were those of fluorosis and molybdenosis—the former a disease affecting human beings, the latter affecting cattle and sheep. It may be of interest to note, in passing, that one of the authorities quoted by a speaker on fluorosis was Dr. Ockerse of the Union Department of Public Health, in whose researches our Geological Survey has been able to play a small part.

One of the services the geologist can give to the medical man in his researches into the effect of various "trace elements" on human or other animals is to forecast the degree of probability of occurrence of such elements in soils or in underground waters at any point. There are other points of contact between the sciences of Geology and Medicine, such as the study of affections of lungs by dust of various kinds and sizes and the pollution of water supply; but it is much to be regretted that the actual contact between geologists and medical authorities is not yet as close as it ought to be. Collaboration between the two groups, however, need not wait for the onset of the post-war period.

In thus indicating some of the lines along which geology may prove to be of "practical" value in the years to come, I have been exploring what might be called the "frontiers of geology." I should not, however, be drawing a true picture if I left you unmindful of the fact that our science is a "study," that it seeks to determine the "when," "how," and "why" of earth history, and that, in so doing, it investigates matters which appear to have no immediate or even far-off practical bearing. In so doing it adds to the sum-total of human knowledge and opens up for our inspection vistas stretching back through those vast aeons to the birth of our planet.

This in itself is important. Indeed, Dr. J. C. Merriam, the famous head of the Carnegie Institution, was bold enough to say that it is important that among those who come into the range of influence of a knowledge of those features of nature presenting exceptional illustration of the story of the earth, there should be included as many as possible of the outstanding individuals who ultimately have influence in guidance of the great affairs of the world. You will agree, I think, that this is a somewhat cryptic utterance. It means, I take it, that our leaders should be, with their other attributes, geologists; I doubt whether even the most enthusiastically bigoted geologist would suggest the converse proposition, that geologists should be our leaders!

It is undeniable that the research side of geology, the enquiry into the when or how or why, has an almost irresistible fascination for most of the devotees of the science. It is almost as undeniable that, before the war, geological research had to be undertaken in the majority of cases, for financial reasons, as a sort of "side line" by men who had to live by teaching the subject, by practising it, or in some non-geological avocation. In this, geology was probably neither better nor worse off than its sister sciences. Much work was, however, done in many of the various parts of the subject; nevertheless, very much more remains to be done and in certain branches of this widespread science we have scarcely made a beginning with our investigations.

To obtain an illustration of this last statement I picked up, almost at random, a volume published by the Geological Society of America in 1939, a few months before the outbreak of war, which contained a number of anniversary day addresses. The first of them, by Dr. A. L. Day, is entitled " The Hot Spring Problem " and finishes with this statement: "Our observations " (which, incidentally, were made mainly in the Yellowstone Park and extended over 12 years or so) " are quite obviously incomplete, so that it is yet hardly possible to dignify these details by the name of theory, but we may perhaps venture to hope that at the end of the next 25 year cycle geysers will have found a reasonably complete and adequate explanation."

There follows an address by Dr. C. W. Gilmore on " Recent Progress in Reptilian Palaeontology." He completes his address by saying "To the future we may look forward with optimism, for the large collections of unstudied materials already in hand and the extended studies under way promise much for future progress not only of reptilian but of all palaeontology."

Other addresses deal with " The Rise of Physiography," " Regional Departures from Ideal Isostasy," " Deformation of the Earth's Crust," " Contribution of Geology to Shaping Ideas on the Meaning of History," and " Ice Ages in the Geological Column;" and all of them have the same thread running through them—that there are far more facts to be discovered than we have as yet learned and that the scope of geological research is as wide and as deep as the earth itself. This variety of opportunities is one of the great attractions of the subject. No enthusiast need seek far for a sphere in which he may exercise his powers of observation and then his powers of deduction; and he will not lack for fellow-students who will either be prepared at all times to dispute with him the logic of his conclusions or pretend to be scornful of the lack of interest inherent in the subject he has chosen. A witty Professor at a South African University once started an address by stating " Glacial geology leaves me cold; and palaeontology is as dry as the old bones with which it deals," and then proceeded to discourse on certain petrological problems which at least one of his hearers might have stigmatised as being as hard as the rocks whose origin the speaker was trying to unravel.

In geological research it is possible for many paths to be travelled; but each is so long that no one man can hope to travel very far along any of them nor to know much of the countries through which no more than a few pass. All, however, lead to the one end; and the more travellers who proceed along them hopefully and purposefully, the shorter will the journey seem to be. In the post-war world it should be made easier for these travellers than it has been in the past.

One question at least remains to be posed. Will geological research in the post-war period be orientated by the demands of the " practical " man or will the spirit of abstruse and scien-

tific investigation be permitted to wander where it will? The answer of any man to this probably depends upon his individual conception of the structure and functions of post-war society. It seems to me that the true aim of any science should be the service of humanity, both in the mass and as individuals, and that, therefore, geological research should be at the same time both planned and free. It is worthy of note that, in what is possibly the most severely practical State of modern times (the U.S.S.R.) one finds research workers in such "unpractical" fields as vertebrate palaeontology encouraged in every way to pursue their studies and honoured for the results they obtain while, at the same time, research in other branches of geology is planned and carried out in order to meet some essential practical need of the State.

Finally, I should like to stress the international character of geological science as of all other sciences. The earth is a whole; those who study it should study it as a whole and should take no cognisance of the artificial boundaries which are drawn by man between State and State. To confine our investigations and our thoughts to any single portion of the earth's surface is ultimately to acquire a very limited outlook. For example, it is not possible to attempt to unravel the history of the land masses of the Southern Hemisphere by confining one's attention to the geological features of South Africa or of South America or of Australia: all must be studied. Lack of opportunity has, in the past, prevented all but a very small minority of geologists from doing more than to read about lands other than their own, and even from meeting their fellows from other lands at International Congresses. Indeed, I think it is likely that the commercial traveller has had a greater mathematical chance of "seeing the world" than the geologist; yet the latter is more likely to solve his local problems if he can come to them with a practical understanding of the more regional problems of which his form but a part.

Of the human and social effects which would ensue from an extension of the opportunities afforded to geologists to acquire practical knowledge outside their own national borders it is not my function to speak; but I am convinced, from my own very limited experience, that the cause of geological science cannot but be furthered and the contribution which the science can make to the future welfare and happiness of humanity cannot but be increased thereby. I would ask pardon for concluding a somewhat disjointed and prosy address by a final thought on the happiness of humanity culled from Euripides:

> "Happy the man whose lot it is to know
> The secrets of the earth. He hastens not
> To work his fellows' hurt by unjust deeds,
> But with rapt admiration contemplates
> Immortal Nature's ageless harmony,
> And how and when her order came to be."

# INDEX TO CONTRIBUTORS.

## SUBJECT INDEX.

INDIAN AGRICULTURAL RESEARCH INSTITUTE LIBRARY, NEW DELHI.

| Date of Issue | Date of Issue | Date of Issue |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

GIPNLK—H:40 I.A.R.I.—29-4- 5—15,000